EPA/600/R-11/072
July 2011

Arsenic Removal from Drinking Water by Adsorptive Media U.S. EPA Demonstration Project at Seely-Brown Village in Pomfret, CT Final Performance Evaluation Report

by

Abraham S.C. Chen[‡]
Ramona Darlington[§]
Lili Wang[‡]

[§]Battelle, Columbus, OH 43201-2693
[‡]ALSA Tech, LLC, Powell, OH 43065-6082

Contract No. EP-C-05-057
Task Order No. 0019

for

Thomas J. Sorg
Task Order Manager

Water Supply and Water Resources Division
National Risk Management Research Laboratory
Cincinnati, Ohio 45268

National Risk Management Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

DISCLAIMER

The work reported in this document was funded by the United States Environmental Protection Agency (EPA) under Task Order 0019 of Contract EP-C-05-057 to Battelle. It has been subjected to the Agency's peer and administrative reviews and has been approved for publication as an EPA document. Any opinions expressed in this paper are those of the author(s) and do not, necessarily, reflect the official positions and policies of the EPA. Any mention of products or trade names does not constitute recommendation for use by the EPA.

FOREWORD

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and groundwater; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

Sally Gutierrez, Director
National Risk Management Research Laboratory

ABSTRACT

This report documents the activities performed for and the results obtained from the arsenic removal treatment technology demonstration project at Seely-Brown Village in Pomfret, CT. The objectives of the project were to evaluate the effectiveness of ArsenX^{np} adsorption media in removing arsenic to meet the new arsenic maximum contaminant level (MCL) of 10 µg/L. Additionally, this project evaluated (1) the reliability of the treatment system, (2) the required system operation and maintenance (O&M) and operator skill levels, and (3) the capital and O&M cost of the technology. The project also characterized the water in the distribution system and process residuals produced by the treatment process.

The community water system was supplied by two wells (Wells No. 1 and No. 2). Arsenic concentrations in raw water averaged 25.2 µg/L, existing primarily as soluble As(V). Iron and manganese concentrations were mostly low, either below the method detection limit (MDL) of 25 µg/L (for iron) or averaging 28.3 µg/L or less (for manganese). Elevated particulate iron and manganese (to as high as 1,232 and 709 µg/L, respectively) were measured occasionally during the study period, and had to be removed by pre-filters.

The 15-gal/min (gpm) arsenic treatment system consisted of a pre-filter and two 12-in × 52-in lead/lag vessels, each containing 2.3 ft^3 of ArsenX^{np} or LayneRT^{TM} media. Both media are engineered hybrid inorganic/organic sorbents consisting of hydrous iron oxide nanoparticles impregnated into anion exchange resin beads. Operation of the system began on February 4, 2009. ArsenX^{np} was evaluated in Study Period I from February 4, 2009, through December 2, 2009. Replacement vessels loaded with LayneRT^{TM} were put online after arsenic levels in system effluent had reached 10 µg/L. LayneRT™ was evaluated from December 3, 2009, through September 24, 2010. The types of data collected included those for system operation, water quality (both across the treatment train and in the distribution system), process residuals, and capital and O&M cost.

The system operated for 1,060 and 1,096 hr with daily run times averaging 3.6 hr/day in both Study Periods I and II. Total amounts of water produced by Wells No. 1 and 2 (that operated simultaneously) in the two study periods were 581,200 and 606,600 gal, respectively, which were comparable to the amounts registered by two totalizers installed after the two adsorption vessels. Based on a flow meter installed downstream of Vessel B, system flowrates averaged 9.6 gpm, equivalent to an average empty bed contact time (EBCT) of 1.8 min/vessel and an average hydraulic loading rate of 12.1 gpm/ft^2. The design EBCT and hydraulic loading rate were 1.2 min and 19 gpm/ft^2, respectively.

Both soluble As(V) and soluble As(III) were removed by ArsenX^{np} and LayneRT^{TM}, but breakthrough 10 µg/L from both media occurred rather early at 15,000 to 18,000 bed volumes (BV). BV was calculated based on 2.3 ft^3 of media in the lead vessel. Short run lengths experienced might be caused, in part, by phosphorus, as a competing anion, and/or coating of the media by iron and/or manganese particulate.

Comparison of distribution system water sampling results before and after the system startup showed a significant decrease in arsenic concentrations, which were either similar to or somewhat higher than those in system effluent. Neither lead nor copper concentrations were affected by the operation of the system.

The capital investment cost for the system was $17,255, including $11,345 for equipment and site engineering and $5,910 for installation. Using the system's rated capacity of 15 gpm (21,600 gal/day [gpd]), the normalized capital cost was $1,150.33/gpm ($0.80/gpd). The O&M cost included the cost for media replacement and disposal, pre-filter replacement, and labor. A cost curve was created to project the cost for media replacement and disposal based on the media run length experienced during an adsorption run.

CONTENTS

APPENDICES

FIGURES

TABLES

ABBREVIATIONS AND ACRONYMS

AAL	American Analytical Laboratories
Al	aluminum
AM	adsorptive media
As	arsenic
ATS	Aquatic Treatment Systems
bgs	below ground surface
BV	bed volume
Ca	calcium
Cl	chloride
C/F	coagulation/filtration
CRF	capital recovery factor
DO	dissolved oxygen
DPH	Department of Public Health
DWS	Drinking Water Section
EBCT	empty bed contact time
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
gpd	gallons per day
gph	gallons per hour
gpm	gallons per minute
HIX	hybrid ion exchanger
hp	horsepower
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IR	Iron Removal
IX	ion exchange
LCR	Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
MEI	Magnesium Elektron, Inc.;
Mg	magnesium
Mn	manganese
mV	millivolts
Na	sodium
NA	not analyzed
NaOCl	sodium hypochlorite

ABBREVIATIONS AND ACRONYMS (Continued)

NRMRL	National Risk Management Research Laboratory
NS	not sampled
NSF	NSF International
NTU	nephelometric turbidity unit
O&M	operation and maintenance
OIT	Oregon Institute of Technology
ORD	Office of Research and Development
ORP	oxidation-reduction potential
PCBs	polychlorinated biphenyls
PO_4	orthophosphate
POU	point-of-use
psi	pounds per square inch
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
RFP	Request for Proposal
RO	reverse osmosis
RPD	relative percent difference
Sb	antimony
SDWA	Safe Drinking Water Act
SiO_2	silica
SMCL	secondary maximum contaminant level
$SO4^{2-}$	sulfate
STS	Severn Trent Services
TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
TEM	transmission electron microscopy
TOC	total organic carbon

ACKNOWLEDGMENTS

The authors wish to extend their sincere appreciation to Ms. Cathy Grant of Seely-Brown Village for monitoring operation of the arsenic removal system and collecting samples from the treatment and distribution systems throughout the performance evaluation study. This performance evaluation would not have been possible without her support and dedication.

1.0 INTRODUCTION

1.1 Background

The Safe Drinking Water Act (SDWA) mandates that the U. S. Environmental Protection Agency (EPA) identify and regulate drinking water contaminants that may have adverse human health effects and that are known or anticipated to occur in public water supply systems. In 1975, under the SDWA, EPA established a maximum contaminant level (MCL) for arsenic (As) at 0.05 mg/L. Amended in 1996, the SDWA required that EPA develop an arsenic research strategy and publish a proposal to revise the arsenic MCL by January 2000. On January 18, 2001, EPA finalized the arsenic MCL at 0.01 mg/L (EPA, 2001). In order to clarify the implementation of the original rule, EPA revised the rule text on March 25, 2003, to express the MCL as 0.010 mg/L (10 µg/L) (EPA, 2003). The final rule required all community and non-transient, non-community water systems to comply with the new standard by January 23, 2006.

In October 2001, EPA announced an initiative for additional research and development of cost-effective technologies to help small community water systems (<10,000 customers) meet the new arsenic standard, and to provide technical assistance to operators of small systems to reduce compliance costs. As part of this Arsenic Rule Implementation Research Program, EPA's Office of Research and Development (ORD) proposed a project to conduct a series of full-scale, on-site demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement was published in the *Federal Register* requesting water utilities interested in participating in Round 1 of this EPA-sponsored demonstration program to provide information on their water systems. In June 2002, EPA selected 17 out of 115 sites to host the demonstration studies.

In September 2002, EPA solicited proposals from engineering firms and vendors for cost-effective arsenic removal treatment technologies for the 17 host sites. EPA received 70 technical proposals for the 17 host sites, with each site receiving from one to six proposals. In April 2003, an independent technical panel reviewed the proposals and provided its recommendations to EPA on the technologies that it determined were acceptable for the demonstration at each site. Because of funding limitations and other technical reasons, only 12 of the 17 sites were selected for the demonstration project. Using the information provided by the review panel, EPA, in cooperation with the host sites and the drinking water programs of the respective states, selected one technical proposal for each site.

In 2003, EPA initiated Round 2 arsenic technology demonstration projects that were partially funded with Congressional add-on funding to the EPA budget. In June 2003, EPA selected 32 potential demonstration sites. In September 2003, EPA again solicited proposals from engineering firms and vendors for arsenic removal technologies. EPA received 148 technical proposals for the 32 host sites, with each site receiving from two to eight proposals. In April 2004, another technical panel was convened by EPA to review the proposals and provide recommendations to EPA with the number of proposals per site ranging from none (for two sites) to a maximum of four. The final selection of the treatment technology at the sites that received at least one proposal was made, again, through a joint effort by EPA, the state regulators, and the host site. Since then, four sites have withdrawn from the demonstration program, reducing the number of sites to 28.

With additional funding from Congress, EPA selected 10 more sites for demonstration under Round 2a. Somewhat different from the Round 1 and Round 2 selection process, Battelle, under EPA's guidance, issued a Request for Proposal (RFP) on February 14, 2007, to solicit technology proposals from vendors and engineering firms. Upon closing of the RFP on April 13, 2007, Battelle received from 14 vendors a total of 44 proposals, which were reviewed by a three-expert technical review panel convened at EPA on May 2 and 3, 2007. Copies of the proposals and recommendations of the review panel were later provided to and discussed with representatives of the 10 host sites and state regulators in a technology selection meeting held at each host site during April through August 2007. The final selections of the treatment technology were made, again, through a joint effort by EPA, the respective state regulators, and the host sites. A 15-gal/min (gpm) ArsenX^{np} adsorption adsorptive media (AM) system fabricated by SolmeteX (which was later acquired by Layne Christensen Company in December 2007) was selected for demonstration at Seely-Brown Village in Pomfret, CT.

As of June 2011, all 50 systems were operational and the performance evaluations of 49 systems were completed.

1.2 Treatment Technologies for Arsenic Removal

Technologies selected for Rounds 1, 2, and 2a demonstration included AM, iron removal (IR), coagulation/filtration (C/F), ion exchange (IX), reverse osmosis (RO), point-of-use (POU) RO, and system/process modification. Table 1-1 summarizes the locations, technologies, vendors, system flowrates, and key source water quality parameters (including As, iron [Fe], and pH). Table 1-2 presents the number of sites for each technology. AM technology was demonstrated at 30 sites, including four with IR pretreatment. IR technology was demonstrated at 12 sites, including four with supplemental iron addition. C/F, IX, and RO technologies were demonstrated at three, two, and one sites, respectively. The Sunset Ranch Development site that demonstrated POU RO technology had nine under-the-sink RO units. The Oregon Institute of Technology (OIT) site classified under AM had three AM systems and eight POU AM units. The Lidgerwood site encompassed only system/process modifications. An overview of the technology selection and system design for the 12 Round 1 demonstration sites and the associated capital costs is provided in two EPA reports (Wang et al., 2004; Chen et al., 2004), which are posted on the EPA Web site at http://www.epa.gov/ORD/NRMRL/arsenic/resource.htm.

1.3 Project Objectives

The objective of the arsenic demonstration program was to conduct full-scale performance evaluations of treatment technologies for arsenic removal from drinking water supplies. The specific objectives were to:

- Evaluate the performance of the arsenic removal technologies for use on small systems.
- Determine the required system operation and maintenance (O&M) and operator skill levels.
- Characterize process residuals produced by the technologies.
- Determine the capital and O&M cost of the technologies.

This report summarizes the performance of ArsenX^{np} AM at Seely-Brown Village in Pomfret, CT, from February 4, 2009, through September 24, 2010. The types of data collected included system operation, water quality (both across the treatment train and in the distribution system), residuals, and capital and O&M cost.

Table 1-1. Summary of Rounds 1, 2, and 2a Arsenic Removal Demonstration Locations, Technologies, and Source Water Quality

Demonstration Location	Site Name	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality		
					As (µg/L)	Fe (µg/L)	pH (S.U.)
Northeast/Ohio							
Carmel, ME	Carmel Elementary School	RO	Norlen's Water	1,200 gpd	21	<25	7.9
Wales, ME	Springbrook Mobile Home Park	AM (A/I Complex)	ATS	14	38[a]	<25	8.6
Bow, NH	White Rock Water Company	AM (G2)	ADI	70[b]	39	<25	7.7
Goffstown, NH	Orchard Highlands Subdivision	AM (E33)	AdEdge	10	33	<25	6.9
Rollinsford, NH	Rollinsford Water and Sewer District	AM (E33)	AdEdge	100	36[a]	46	8.2
Dummerston, VT	Charette Mobile Home Park	AM (A/I Complex)	ATS	22	30	<25	7.9
Houghton, NY[c]	Town of Caneadea	IR (Macrolite)	Kinetico	550	27[a]	1,806[d]	7.6
Woodstock, CT	Woodstock Middle School	AM (Adsorbsia)	Siemens	17	21	<25	7.7
Pomfret, CT	Seely-Brown Village	AM (ArsenX^{np})	SolmeteX	15	25	<25	7.3
Felton, DE	Town of Felton	C/F (Macrolite)	Kinetico	375	30[a]	48	8.2
Stevensville, MD	Queen Anne's County	AM (E33)	STS	300	19[a]	270[d]	7.3
Conneaut Lake, PA	Conneaut Lake Park	IR (Greensand Plus) with ID	AdEdge	250	28[a]	157[d]	8.0
Buckeye Lake, OH	Buckeye Lake Head Start Building	AM (ARM 200)	Kinetico	10	15[a]	1,312[d]	7.6
Springfield, OH	Chateau Estates Mobile Home Park	IR & AM (E33)	AdEdge	250[e]	25[a]	1,615[d]	7.3
Great Lakes/Interior Plains							
Brown City, MI	City of Brown City	AM (E33)	STS	640	14[a]	127[d]	7.3
Pentwater, MI	Village of Pentwater	IR (Macrolite) with ID	Kinetico	400	13[a]	466[d]	6.9
Sandusky, MI	City of Sandusky	IR (Aeralater)	Siemens	340[e]	16[a]	1,387[d]	6.9
Delavan, WI	Vintage on the Ponds	IR (Macrolite)	Kinetico	40	20[a]	1,499[d]	7.5
Goshen, IN	Clinton Christian School	IR & AM (E33)	AdEdge	25	29[a]	810[d]	7.4
Fountain City, IN	Northeastern Elementary School	IR (G2)	US Water	60	27[a]	1,547[d]	7.5
Waynesville, IL	Village of Waynesville	IR (Greensand Plus)	Peerless	96	32[a]	2,543[d]	7.1
Geneseo Hills, IL	Geneseo Hills Subdivision	AM (E33)	AdEdge	200	25[a]	248[d]	7.4
Greenville, WI	Town of Greenville	IR (Macrolite)	Kinetico	375	17[a]	7,827[d]	7.3
Climax, MN	City of Climax	IR (Macrolite) with ID	Kinetico	140	39[a]	546[d]	7.4
Sabin, MN	City of Sabin	IR (Macrolite)	Kinetico	250	34[a]	1,470[d]	7.3
Sauk Centre, MN	Big Sauk Lake Mobile Home Park	IR (Macrolite)	Kinetico	20	25[a]	3,078[d]	7.1
Stewart, MN	City of Stewart	IR &AM (E33)	AdEdge	250	42[a]	1,344[d]	7.7
Lidgerwood, ND	City of Lidgerwood	Process Modification	Kinetico	250	146[a]	1,325[d]	7.2
Lead, SD	Terry Trojan Water District	AM (ArsenX^{np})	SolmeteX	75	24	<25	7.3
Midwest/Southwest							
Willard, UT	Hot Springs Mobile Home Park	IR & AM (Adsorbsia)	Filter Tech	30	15.4[a]	332[d]	7.5
Arnaudville, LA	United Water Systems	IR (Macrolite)	Kinetico	770[e]	35[a]	2,068[d]	7.0
Alvin, TX	Oak Manor Municipal Utility District	AM (E33)	STS	150	19[a]	95	7.8
Bruni, TX	Webb Consolidated Independent School District	AM (E33)	AdEdge	40	56[a]	<25	8.0

Table 1-1. Summary of Rounds 1, 2, and 2a Arsenic Removal Demonstration Locations, Technologies, and Source Water Quality (Continued)

Demonstration Location	Site Name	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality As (µg/L)	Source Water Quality Fe (µg/L)	Source Water Quality pH (S.U.)
Wellman, TX	City of Wellman	AM (E33)	AdEdge	100	45	<25	7.7
Anthony, NM	Desert Sands Mutual Domestic Water Consumers Association	AM (E33)	STS	320	23[(a)]	39	7.7
Nambe Pueblo, NM	Nambe Pueblo Tribe	AM (E33)	AdEdge	145	33	<25	8.5
Taos, NM	Town of Taos	AM (E33)	STS	450	14	59	9.5
Rimrock, AZ	Arizona Water Company	AM (E33)	AdEdge	90[(b)]	50	170	7.2
Tohono O'odham Nation, AZ	Tohono O'odham Utility Authority	AM (E33)	AdEdge	50	32	<25	8.2
Valley Vista, AZ	Arizona Water Company	AM (AAFS50/ARM 200)	Kinetico	37	41	<25	7.8
Far West							
Three Forks, MT	City of Three Forks	C/F (Macrolite)	Kinetico	250	64	<25	7.5
Fruitland, ID	City of Fruitland	IX (A300E)	Kinetico	250	44	<25	7.4
Homedale, ID	Sunset Ranch Development	POU RO[(f)]	Kinetico	75 gpd	52	134	7.5
Okanogan, WA	City of Okanogan	C/F (Electromedia-I)	Filtronics	750	18	69[(d)]	8.0
Klamath Falls, OR	Oregon Institute of Technology	POE AM (Adsorbsia/ ARM 200/ArsenX^{np}) and POU AM (ARM 200)[(g)]	Kinetico	60/60/30	33	<25	7.9
Vale, OR	City of Vale	IX (Arsenex II)	Kinetico	525	17	<25	7.5
Reno, NV	South Truckee Meadows General Improvement District	AM (GFH)	Siemens	350	39	<25	7.4
Susanville, CA	Richmond School District	AM (A/I Complex)	ATS	12	37[(a)]	125	7.5
Lake Isabella, CA	Upper Bodfish Well CH2-A	AM (HIX)	VEETech	50	35	125	7.5
Tehachapi, CA	Golden Hills Community Service District	AM (Isolux)	MEI	150	15	<25	6.9

AM = adsorptive media process; C/F = coagulation/filtration; HIX = hybrid ion exchanger; IR = iron removal; IR with ID = iron removal with iron addition; IX = ion exchange process; RO = reverse osmosis

ATS = Aquatic Treatment Systems; MEI = Magnesium Elektron, Inc.; STS = Severn Trent Services

(a) Arsenic existing mostly as As(III).

(b) Design flowrate reduced by 50% due to system reconfiguration from parallel to series operation.

(c) Selected originally to replace Village of Lyman, NE site, which withdrew from program in June 2006; withdrew from program in 2007 and replaced with a home system in Lewisburg, OH.

(d) Iron existing mostly as Fe(II).

(e) Facilities upgraded systems in Springfield, OH from 150 to 250 gpm, Sandusky, MI from 210 to 340 gpm, and Arnaudville, LA from 385 to 770 gpm.

(f) Including nine residential units.

(g) Including eight under-the-sink units.

Table 1-2. Number of Demonstration Sites Under Each Arsenic Removal Technology

Technologies	Number of Sites
Adsorptive Media[a]	26
Adsorptive Media with Iron Removal Pretreatment	4
Iron Removal (Oxidation/Filtration)	8
Iron Removal with Supplemental Iron Addition	4
Coagulation/Filtration	3
Ion Exchange	2
Reverse Osmosis	1
Point-of-use Reverse Osmosis[b]	1
System/Process Modifications	1

(a) OIT site at Klamath Falls, OR had three AM systems and eight POU AM units.
(b) Including nine under-the-sink RO units.

2.0 SUMMARY AND CONCLUSIONS

Based on the information collected during the 20 months of system operation, the following summary and conclusions were made relating to the overall objectives of the treatment technology demonstration study.

Performance of the arsenic removal technology for use on small systems:

- ArsenX^{np} and LayneRT^{TM} media were capable of removing both soluble As(III) and soluble As(V) from source water. However, run lengths for both media were short, spanning from approximately 15,000 bed volumes (BV) for ArsenX^{np} to 18,000 BV for LayneRT^{TM} (BV was calculated based on 2.3 ft^3 [or 17.2 gal] of media in the lead vessel).
- Arsenic concentrations in distribution system water were significantly reduced from the baseline level of 24.3 μg/L (on average) to <10.4 μg/L for ArsenX^{np} and <1.4 μg/L for LayneRT^{TM}. Arsenic levels in distribution water mirrored essentially those in treatment system effluent water.
- System operation did not appear to have any effect on lead and copper levels in the distribution system.

Required system O&M and operator skill levels:

- The daily demand on the operator was typically 20 min to visually inspect the system and record operational parameters. No other special skill was required to operate the system.

Process residuals produced by the technology:

- Residuals produced by system operations included spent filters and spent ArsenX^{np} media. The spent filters were disposed of with the trash. The spent ArsenX^{np} media was regenerated with other spent media from the vendor's point-of-entry product line and used in non-drinking water applications.

Capital and O&M cost of the technology:

- The annualized unit capital cost was $0.21/1,000 gal of water treated if the system operated at a 100% utilization rate. At an actual use rate of 706,000 gal per year, the unit cost increased to $2.31/1,000 gal of water treated.
- The O&M cost per 1,000 gal of water treated was relatively high at $3.01 for pre-filter replacement and labor plus the media replacement and disposal cost.

3.0 MATERIALS AND METHODS

3.1 General Project Approach

Following the predemonstration activities summarized in Table 3-1, the performance evaluation study of the ArsenX^{np} arsenic removal system began on February 4, 2009, and ended on September 24, 2010. Table 3-2 summarizes types of data collected and considered as part of the technology evaluation process. The overall system performance was evaluated based on its ability to consistently remove arsenic to below the MCL of 10 μg/L through the collection of water samples across the treatment train, as described in the Study Plan (Battelle, 2008). The reliability of the system was evaluated by tracking the unscheduled system downtime and frequency and extent of repair and replacement. The plant operator recorded unscheduled downtime and repair information on a Repair and Maintenance Log Sheet.

Table 3-1. Predemonstration Study Activities and Completion Dates

Activity	Date
Introductory Meeting Held	December 15, 2006
Technology Selection Meeting Held	June 12, 2007
Project Planning Meeting Held	July 23, 2007
Draft Letter of Understanding Issued	July 30, 2007
Final Letter of Understanding Issued	August 10, 2007
Request for Quotation Issued to Vendor	February 21, 2008
Revised Vendor Quotation Received by Battelle	March 10, 2008
Purchase Order Completed and Signed	April 4, 2008
Engineering Package Submitted to CT DPH	May 7, 2008
Permit Issued by CT DPH	November 26, 2008
Equipment Arrived at Site	January 6, 2009
Final Study Plan Issued	January 09, 2009
System Installation and Shakedown Completed	January 21, 2009
System Operation Begun	February 4, 2009
Performance Evaluation Study Begun	February 4, 2009

DPH = Department of Public Health

O&M and operator skill requirements were evaluated based on a combination of quantitative data and qualitative considerations, including the need for pre- and/or post-treatment, level of system automation, extent of preventative maintenance activities, frequency of chemical and/or media handling and inventory, and general knowledge needed for relevant chemical processes and related health and safety practices. Staffing requirements for the system operation were recorded on an Operator Labor Hour Log Sheet.

Quantities of aqueous and solid residuals generated were estimated by tracking the volume of backwash wastewater produced during each backwash cycle. Backwash wastewater and solids were sampled and analyzed for chemical characteristics.

The cost of the system was evaluated based on the capital cost per gal/min (or gal/day [gpd]) of design capacity and the O&M cost per 1,000 gal of water treated. This task required tracking the capital cost for equipment, site engineering, and installation, as well as the O&M cost for media replacement and disposal, chemical supply, electrical usage, and labor.

Table 3-2. Evaluation Objectives and Supporting Data Collection Activities

Evaluation Objectives	Data Collection
Performance	–Ability to consistently meet 10 μg/L of arsenic MCL in treated water
Reliability	–Unscheduled system downtime –Frequency and extent of repairs including a description of problems encountered, materials and supplies needed, and associated labor and cost incurred
System O&M and Operator Skill Requirements	–Pre- and post-treatment requirements –Level of automation for system operation and data collection –Staffing requirements including number of operators and laborers –Task analysis of preventative maintenance including number, frequency, and complexity of tasks –General knowledge needed for relevant chemical processes and health and safety practices
Residual Management	–Quantity and characteristics of aqueous and solid residuals generated by system operation
Cost-Effectiveness	–Capital cost for equipment, engineering, and installation –O&M cost for chemical usage, electricity consumption, and labor

3.2 System O&M and Cost Data Collection

The plant operator performed daily, biweekly, and monthly system O&M and data collection according to instructions provided by the vendor and Battelle. On a regular basis, the plant operator recorded system operational data such as pressure, flowrate, totalizer, and hour meter readings on a System Operation Log Sheet and conducted visual inspections to ensure normal system operations. If any problems occurred, the plant operator contacted the Battelle Study Lead, who determined if the vendor should be contacted for troubleshooting. The plant operator recorded all relevant information, including the problems encountered, course of actions taken, materials and supplies used, and associated cost and labor incurred on the Repair and Maintenance Log Sheet. Occasionally, the plant operator also measured temperature, pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), and recorded the data on an Onsite Water Quality Parameters Log Sheet.

The capital cost for the arsenic removal system consisted of the cost for equipment, site engineering, and system installation. The O&M cost consisted of the expenditure for media replacement and disposal, chemical supply, electricity consumption, and labor. Labor for various activities, such as the routine system O&M, troubleshooting and repairs, and demonstration-related work, was tracked using an Operator Labor Hour Log Sheet. The routine system O&M included activities such as completing field logs, ordering supplies, performing system inspections, and others as recommended by the vendor. The labor for demonstration-related work, including activities such as performing field measurements, collecting and shipping samples, and communicating with the Battelle Study Lead and the vendor, was recorded, but not used for cost analysis.

3.3 Sample Collection Procedures and Schedules

To evaluate system performance, samples were collected at the wellheads, across the treatment plant, and from the distribution system. Table 3-3 presents the sampling schedules and analytes measured during each sampling event. Specific sampling requirements for analytical methods, sample volumes, containers, preservation, and holding times are presented in Table 4-1 of the EPA-endorsed Quality Assurance Project Plan (QAPP) (Battelle, 2007). The procedure for arsenic speciation is described in Appendix A of the QAPP.

Table 3-3. Sampling Schedule and Analytes

Sample Type	Sample Locations	No. of Samples	Frequency	Analytes	Sampling Date
Source Water	At Wellhead (IN)	1	Once (during initial site visit)	Onsite: pH, temperature, DO, and ORP Offsite: As (III), As(V), As (total and soluble), Fe (total and soluble), Mn (total and soluble), Sb (total and soluble), V, Na, Ca, Mg, Cl, F, NO_3, NO_2, NH_3, SO_4, SiO_2, P, turbidity, alkalinity, TDS, and TOC	12/15/06
Treatment Plant Water	IN, after vessel A (TA), after vessel B (TB), distribution system (DS)	4	Monthly (with speciation)[a]	Onsite: pH, temperature, DO, and/or ORP Offsite: As(III), As(V), As (total and soluble), Fe (total and soluble), Mn (total and soluble), Ca, Mg, F, NO_3, SO_4, SiO_2, P, turbidity, and alkalinity	See Appendix B
			Monthly (regular without speciation)[b]	Onsite: pH, temperature, DO, and/or ORP Offsite: As (total), Fe (total), Mn (total), SiO_2, P, turbidity, and alkalinity	See Appendix B
Distribution Water	Tap in Kitchen (DS)	1	Monthly	Total As, Fe, Mn, Cu, and Pb, pH, and alkalinity	See Table 4-8

(a) On 08/10/10, 09/07/10, and 10/07/10, analytes reduced to As (total and soluble), Fe (total and soluble), Mn (total and soluble), and P.
(b) "Without Speciation" sampling discontinued after 05/27/10.
DO = dissolved oxygen; ORP = oxidation/reduction potential; TDS = total dissolved solids; TOC = total organic carbon

3.3.1 Source Water. During the initial site visit on December 15, 2006, one set each of source water samples from Wells No. 1 and No. 2 were collected and speciated using arsenic specitation kits (see Section 3.4.1). Sample taps were flushed for several minutes before sampling; special care was taken to avoid agitation, which might cause unwanted oxidation. Analytes for source water samples are listed in Table 3-3.

3.3.2 Treatment Plant Water. During the system performance evaluation study, the plant operator collected water samples across the treatment train every other week. In general, sampling alternated between regular and speciation sampling. Regular sampling involved taking samples at the wellhead (IN), after Vessel A (TA), after Vessel B (TB) and at distribution system (DS) and having them analyzed for the analytes listed under "Regular Sampling" in Table 3-3. Speciation sampling involved collecting and speciating samples onsite at the same four locations and having them analyzed for the analytes listed under "Speciation Sampling" in Table 3-3.

Regular sampling was discontinued after May 27, 2010. Speciation sampling continued, but the frequency was extended from monthly to bi-monthly once on August 10, 2010. Analytes for the last three speciation sampling events in August, September, and October 2010 were reduced to phosphorus and total and soluble arsenic, iron, and manganese.

3.3.3 Backwash Wastewater and Solids. Because the system did not require backwashing, no backwash wastewater or solid samples were collected during the performance evaluation study.

3.3.4 Spent Media. Upon exhaustion, spent ArsenX^{np} in the two adsorption vessels was replaced with LayneRT™ media. The spent media and the vessels was returned to SometeX's facility for rengeneration and disposal, respecively. The spent media was regenerated with other spent media from the vendor's point-of-entry product line and used in non-drinking water applications. .

3.3.5 Distribution System Water. Water samples were collected from the distribution system to determine the impact of the arsenic treatment system on the water chemistry in the distribution system, specifically, the arsenic, lead and copper levels. Prior to system startup from November 17, 2008, through December 17, 2008, four sets of baseline distribution system water samples were collected. The first set of baseline samples was collected from three locations: at the kitchen sink, at the nurses sink, and at the staff dining room sink. All three locations were used by the facility for Lead and Copper Rule (LCR) sampling. The following three sets of baseline samples were taken only from the kitchen sink. After system startup, distribution system water sampling continued monthly at the kitchen sink from March 2009 through May 2010.

The plant operator collected the samples following an instruction sheet developed in accordance with the *Lead and Copper Monitoring and Reporting Guidance for Public Water Systems* (EPA, 2002). The date and time of last water usage before sampling and of actual sample collection were recorded for calculation of stagnation time. All samples were collected from a cold-water faucet that had not been used for at least 6 hr to ensure collection of stagnant water.

3.4 Sampling Logistics

3.4.1 Preparation of Arsenic Speciation Kits. The arsenic field speciation method used an anion exchange resin column to separate soluble arsenic species, As(V) and As(III) (Edwards et al., 1998). Resin columns were prepared in batches at Battelle laboratories in accordance with the procedures detailed in Appendix A of the EPA-endorsed QAPP (Battelle, 2007).

3.4.2 Preparation of Sampling Coolers. For each sampling event, a sample cooler was prepared with the appropriate number and type of sample bottles, disc filters, and/or speciation kits. All sample bottles were new and contained appropriate preservatives. Each sample bottle was affixed with a pre-printed, color-coded label consisting of sample identification (ID), date and time of sample collection, collector's name, site location, sample destination, analysis required, and preservative. The sample ID consisted of a two-letter code for a specific water facility, sampling date, a two-letter code for a specific sampling location, and a one-letter code designating the arsenic speciation bottle (if necessary). The sampling locations at the treatment plant were color-coded for easy identification. The labeled bottles for each sampling location were placed in separate zip-lock bags and packed in the cooler.

In addition, all sampling- and shipping-related materials, such as disposable gloves, sampling instructions, chain-of-custody forms, prepaid/addressed FedEx air bills, and bubble wrap, were included. The chain-of-custody forms and air bills were complete except for the operator's signature and the sample dates and times. After preparation, the sample cooler was sent to the site via FedEx for the following week's sampling event.

3.4.3 Sample Shipping and Handling. After sample collection, samples for offsite analyses were packed carefully in the original coolers with wet ice and shipped to Battelle. Upon receipt, the sample custodian verified that all samples indicated on the chain-of-custody forms were included and intact. Sample IDs were checked against the chain-of-custody forms, and the samples were logged into the laboratory sample receipt log. Discrepancies noted by the sample custodian were addressed with the plant operator by the Battelle Study Lead.

Samples for metals analyses were stored at Battelle's ICP-MS laboratory. Samples for other water analyses were packed in separate coolers and picked up by couriers from American Analytical Laboratories (AAL) in Columbus, OH, which was under contract with Battelle for this demonstration study. The chain-of-custody forms remained with the samples from the time of preparation through analysis and final disposition. All samples were archived by the appropriate laboratories for the respective duration of the required hold time and disposed of properly thereafter.

3.5 Analytical Procedures

The analytical procedures described in detail in Section 4.0 of the EPA-endorsed QAPP (Battelle, 2007) were followed by Battelle's inductively coupled plasma-mass spectrometry (ICP-MS) laboratory and AAL. Laboratory quality assurance/quality control (QA/QC) of all methods followed the prescribed guidelines. Data quality in terms of precision, accuracy, method detection limits (MDL), and completeness met the criteria established in the QAPP (i.e., relative percent difference [RPD] of 20%, percent recovery of 80 to 120%, and completeness of 80%). The QA data associated with each analyte will be presented and evaluated in a QA/QC Summary Report to be prepared under separate cover upon completion of the Arsenic Demonstration Project.

Field measurements of pH, temperature, DO, and ORP were conducted by the plant operator using a VWR Symphony SP90M5 Handheld Multimeter, which was calibrated for pH and DO prior to use following the procedures provided in the user's manual. The ORP probe also was checked for accuracy by measuring the ORP of a standard solution and comparing it to the expected value. The plant operator collected a water sample in a clean, plastic beaker and placed the Symphony SP90M5 probe in the beaker until a stable value was obtained.

4.0 RESULTS AND DISCUSSION

4.1 Facility Description and Pre-existing Treatment System Infrastructure

Located at 400 Deerfield Road in Pomfret, CT, Seely-Brown Village is a nursing home facility, comprised of 32 one-bedroom apartments with approximately 48 residents. The facility is a community water system supplied by two wells (i.e., Wells No. 1 and No. 2). Based on Section III.B.2 of the State of Connecticut DPH Guidelines, the water system must meet an average daily water demand of 4,800 gpd, based on a design population of 64 (or two occupants per living unit) and a design water usage value of 75 gal/day/capita. The actual average daily production at the facility was 1,926 gpd according to Lenard Engineering, the facility's engineer, or 2,800 gpd according to the information submitted by the state to EPA for the demonstration site selection. These average daily production values represent 40% to 58% of the recommended design value for the average daily water demand. Although future expansion of the Seely-Brown Village is under consideration, the treatment system for the EPA demonstration project was sized based on the pre-existing facility infrastructure.

Wells No. 1 and No. 2 are located on the north side of the paved driveway and parking lot and spaced approximately 170 ft from each other. Well No. 1 is 6-in in diameter, installed to a depth of 220 ft below ground surface (bgs) with a casing extending to 120 ft bgs. At the time of installation in September 1993, the well yielded 5 gpm, which is somewhat higher than the 3.6-gpm flowrate measured by the facility in November 2007 and the 4.3-gpm flowrate measured by the vendor in September 2008 (with water pumped to an atmospheric storage tank). Well No. 2 is 6-in in diameter and installed to a depth of 500 ft bgs with a casing extending to 140 ft bgs. At the time of installation in September 1993, the well yielded 6.5 gpm, which is somewhat lower than the 8.9-gpm flowrate measured by the facility in November 2007 and the 7.0-gpm flowrate measured by the vendor in September 2008 (again with water pumped to the atmospheric storage tank). With 35 pounds per square inch (psi) of backpressure applied, well pump flowrates were reduced to 3.3 gpm for Well No. 1 and 4.3 gpm for Well No. 2 based upon measurements taken by the vendor in September 2008. With both wells running simultaneously, it would yield an approximate total flowrate of 8 gpm with 35 psi of backpressure to the system. Each well has an associated raw water sample tap and a well totalizer. A control panel exists to turn the pumps on/off based on water storage tank levels along with a high level alarm (see Figure 4-1).

The wells were originally alternated with water being blended into one 5,000-gal atmospheric storage tank shown in Figure 4-2. From the water storage tank, two skid-mounted, 1.5-horsepower (hp) booster pumps (25 gpm) were used to provide pressure to the distribution system via a 300-gal hydropneumatic tank with a 70/80 psi pressure setting (see Figure 4-2). Pressurized water was sent through two Birm filters (Figure 4-3) for iron removal prior to entering the distribution system (see Figure 4-3). Each Birm vessel was 21-in in diameter (or 2.4 ft^2 in cross-sectional area) with a capacity of 12 gpm. The maximum loading rate to a Birm vessel was 5 gpm/ft^2. The site also had an onsite septic system for wastewater discharge.

4.1.1 Source Water Quality. Source water samples were collected on December 15, 2006, when two Battelle staff members traveled to the site to conduct an introductory meeting for this demonstration project. Table 4-1 presents analytes of interest. The source water also was filtered for soluble arsenic, iron, manganese, and antimony, and then speciated for As(III) and As(V) using the field speciation method modified from Edwards et al. (1998) by Battelle (Wang et al., 2000). In addition, pH, temperature, DO, and ORP were measured onsite using a field meter.

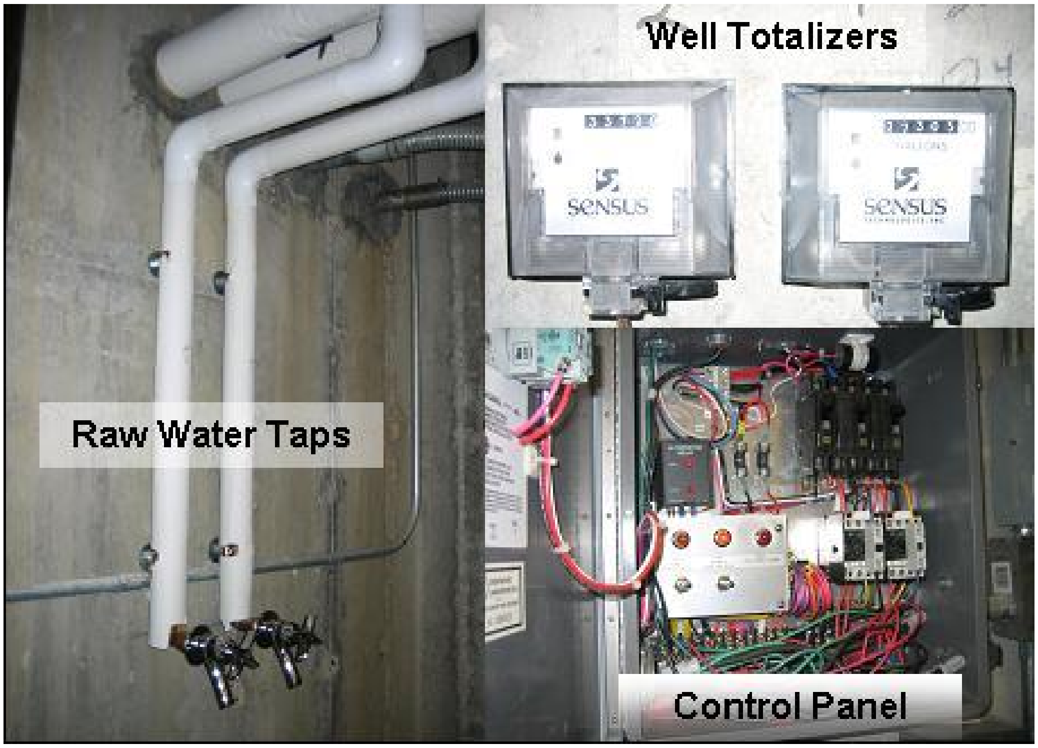


Figure 4-1. Well Instrumentation
(Clockwise from Left: Raw Water Sample Taps, Water Totalizers, Well Pump Control Panel)

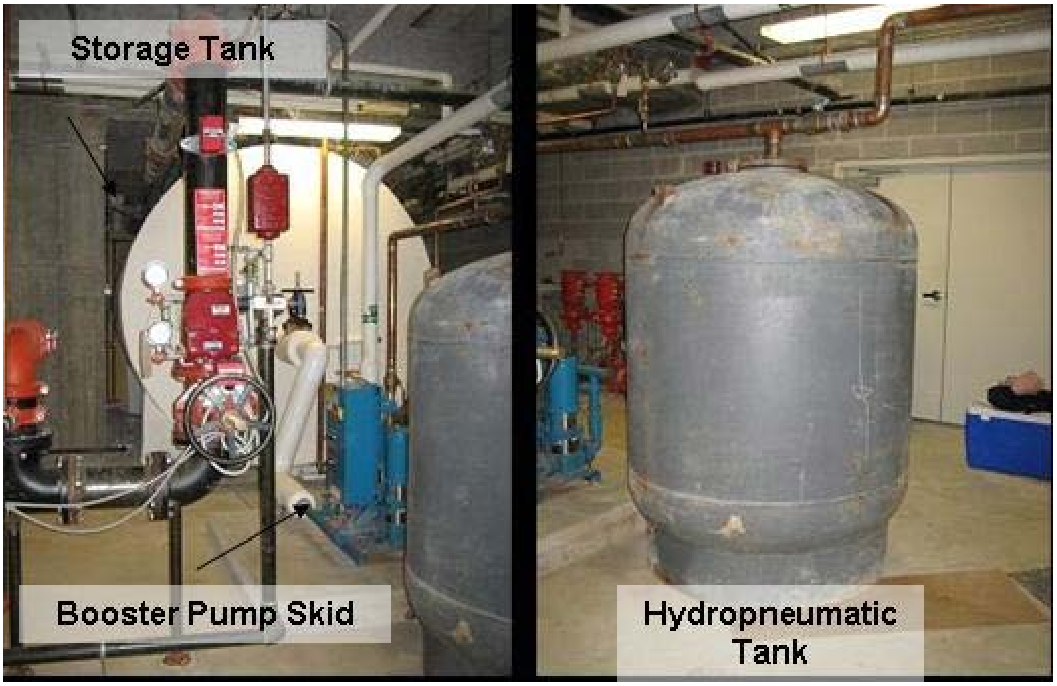


Figure 4-2. 5,000-gal Atmospheric Water Storage Tank, Booster Pump Skid, and 300-gal Hydropneumatic Tank *(White Tank in Background, Blue Skid on Floor, and Grey Tank in Foreground and on Right, respectively)*

Figure 4-3. Parallel Configuration of Birm Filters for Iron Removal

Analytical results from the December 15, 2006, source water sampling event were compared to the pre-site selection data provided by EPA and historical raw water and distribution system water data obtained from the facility/Connecticut DPH. Overall, Battelle's data are comparable to those provided by EPA and the facility. The results of the source water assessment and implications for water treatment are discussed briefly below.

Arsenic. Total arsenic concentrations in source water ranged from 18.0 to 30.0 μg/L. Based on the results obtained by Battelle for Wells No. 1 and No. 2, arsenic was present entirely in the soluble form with 18.6 to 27.7 μg/L existing as As(V) and 1.6 to 2.5 μg/L as As(III). Therefore, As(V) was the predominating species. The low levels of As(III) suggest that treatment via adsorption would be effective without a pre-oxidation step. No prior information on arsenic speciation was available from EPA, Connecticut DPH, or the facility. In the distribution water, total arsenic levels ranged from 13 to 24 μg/L and averaged 20 μg/L.

Table 4-1. Raw and Distribution Water Quality Data at Seely-Brown Village

Parameter	Unit	EPA Data				Battelle Data		Facility Data		
		Well No. 1 Raw Water	Well No. 2 Raw Water	Treated Water	Restroom Treated Water	Well No. 1 Raw Water	Well No. 2 Raw Water	Well No. 1 Raw Water	Well No. 2 Raw Water	Distribution Water[(a)]
Date		05/05/06		05/04/06		12/15/06		11/02/01–11/29/06		
pH	S.U.	NA	NA	NA	NA	6.9	7.6	7.9	7.8	7.7
Temperature	°C	NA	NA	NA	NA	12.7	11.0	NA	NA	NA
DO	mg/L	NA	NA	NA	NA	0.7	3.9	NA	NA	NA
ORP	mV	NA	NA	NA	NA	402	403	NA	NA	NA
Total Alkalinity (as $CaCO_3$)	mg/L	53.1	41.6	47.7	47.4	58.0	46.0	66	NA	77
Total Hardness (as $CaCO_3$)	mg/L	56.1	52.3	53.8	50.1	56.6	55.1	30	<10	17
Turbidity	NTU	NA	NA	NA	NA	0.5	0.4	NA	NA	NA
TDS	mg/L	NA	NA	NA	NA	92	88	NA	NA	NA
TOC	mg/L	NA	NA	NA	NA	<1.0	<1.0	NA	NA	NA
Nitrate (as N)	mg/L	0.07	0.08	0.04	0.04	<0.05	0.07	NA	NA	<0.01–0.18 (<0.01)
Nitrite (as N)	mg/L	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05	NA	NA	NA
Ammonia (as N)	mg/L	0.04	0.03	0.05	0.06	<0.05	<0.05	NA	NA	NA
Chloride	mg/L	NA	NA	NA	NA	3	6	2.8	4.5	3.3–4.0 (3.7)
Fluoride	mg/L	NA	NA	NA	NA	0.3	0.2	NA	NA	<0.1–0.32 (0.19)
Sulfate	mg/L	20.0	20.4	20.4	18.9	18.0	19.0	13	12	16–24 (20)
Silica (as SiO_2)	mg/L	13.9	13.9	13.8	12.8	13.3	13.4	NA	NA	NA
Orthophosphate (as PO_4)	mg/L	<0.005	0.7	0.4	0.3	NA	NA	NA	NA	NA
P (as PO_4)	mg/L	<0.2	1.0	0.6	0.5	0.03	0.95	NA	NA	NA
Al (total)	μg/L	<25	<25	<25	30	NA	NA	NA	NA	NA
As (total)	μg/L	18	28	22	24	19.6	30.0	NA	NA	13–24 (20)
As (soluble)	μg/L	NA	NA	NA	NA	20.2	30.2	NA	NA	NA
As (particulate)	μg/L	NA	NA	NA	NA	<0.1	<0.1	NA	NA	NA
As(III)	μg/L	NA	NA	NA	NA	1.6	2.5	NA	NA	NA
As(V)	μg/L	NA	NA	NA	NA	18.6	27.7	NA	NA	NA
Fe (total)	μg/L	86	144	16	9	<25	27	80	250	30
Fe (soluble)	μg/L	NA	NA	NA	NA	<25	<25	NA	NA	NA
Mn (total)	μg/L	13.0	43.0	<0.4	1.0	10.6	39.9	10	30	10
Mn (soluble)	μg/L	NA	NA	NA	NA	10.2	4.1	NA	NA	NA
Sb (total)	μg/L	<25	<25	<25	<25	<0.1	<0.1	NA	NA	<1
Sb (soluble)	μg/L	NA	NA	NA	NA	<0.1	<0.1	NA	NA	NA
V (total)	μg/L	NA	NA	NA	NA	0.4	0.4	NA	NA	NA
Na (total)	mg/L	9.8	7.0	8.3	7.7	9.6	7.2	10	7.2	8.1–9.8 (9.0)
Ca (total)	mg/L	20.1	17.2	18.6	17.3	20.2	18.1	NA	NA	NA
Mg (total)	mg/L	1.4	2.3	1.8	1.7	1.5	2.4	NA	NA	NA

(a) minimum–maximum [average]
DO = dissolved oxygen; NA = not available; ORP = oxidation-reduction potential; TDS = total dissolved solids; TOC = total organic carbon

Iron and Manganese. Total iron concentrations in source water ranged from <25 to 250 μg/L. For Well No. 1, iron concentrations ranged from <25 to 86 μg/L and averaged 60 μg/L. For Well No. 2, iron concentrations ranged from 27 to 250 μg/L and averaged 140 μg/L. These values are below the 300 μg/L secondary maximum contaminant level (SMCL). Adsorption technologies work best with low influent iron levels because of the potential for iron fouling of the media bed. This site is a good candidate for adsorption because of the low iron levels. However, total iron levels were <25 μg/L in Well No. 1 and 27 μg/L in Well No. 2 during the December 15, 2006 source water sampling event. The reason for historically elevated iron levels was not determined.

Total manganese levels in Well No. 1 source water ranged from 10.0 to 13.0 μg/L, which is well below the SMCL of 50 μg/L for manganese. Total manganese levels for Well No. 2 were higher at 30.0 to 43.0 μg/L, which also is below the SMCL. Overall, the two wells exhibited somewhat different water chemistry, with Well No. 2 having higher levels of total arsenic, iron, and manganese.

Competing Anions. Adsorption of arsenic can be influenced by competing anions such as silica and phosphorus. Based on the results shown in Table 2-1, silica concentrations at 13.3 to 13.9 mg/L in raw water did not appear to be high enough to impact adsorption. Total phosphorus levels varied significantly between the wells with 0.03 to <0.2 mg/L (as PO_4) in Well No. 1 water and 0.95 to 1.0 mg/L (as PO_4) in Well No. 2 water, based on the data collected by EPA and Battelle. High levels of phosphorus can significantly affect arsenic removal and shorten useful media life.

Other Water Quality Parameters. Battelle's data indicate a moderate pH of 6.9 for Well No. 1 and 7.6 for Well No. 2; this is within the commonly-agreed target range of 5.5 to 8.5 for arsenic removal. The relatively lower pH of Well No. 1 may result in more effective arsenic removal via adsorption compared to Well No. 2. The facility pH data appear to be significantly higher, ranging from 7.8 to 7.9.

Based on Battelle's data, total hardness concentrations ranged from 55.1 to 56.6 mg/L (as $CaCO_3$); turbidity from 0.4 to 0.5 nephelometric turbidity unit (NTU); TDS from 88 to 92 mg/L; nitrate from less than 0.05 to 0.07 mg/L; and sodium from 7.2 to 9.6 mg/L. TOC concentrations were <1.0 mg/L and ammonia concentrations were <0.05 mg/L (as N).

All other analytes were below detection limits and/or anticipated to be low enough not to adversely affect the arsenic removal process. Radionuclides, including combined radium, combined uranium, and gross alpha, were non-detect at the site based on quarterly compliance monitoring conducted in 2006.

4.1.2 Predemonstration Treated Water Quality. Treated water quality was similar to raw water quality except for noticeably lower iron and arsenic levels. The lower iron levels in treated water could be due to treatment of raw water by Birm that are known to reduce iron levels in water. Treated water samples were not collected by Battelle or EPA at the time of source water sampling.

4.1.3 Distribution System. The distribution system for Seely-Brown Village consists of connections to serve 32 apartments. The distribution system material is comprised primarily of copper piping. One location within the nursing home was selected for monthly baseline and distribution sampling to evaluate the effect of the treatment system on the distribution system water quality.

The Seely-Brown Village operator is a Class II operator. Compliance sampling for the entry point includes arsenic (quarterly); radionuclides including gross alpha, uranium, and combined radium (quarterly); nitrate and nitrite (yearly); organic chemicals (once every three years); pesticides, herbicides, and polychlorinated biphenyls (PCBs) (once every three years); and inorganic chemicals (once every three years). Compliance sampling for the distribution system includes total coliform (monthly); physical parameters (monthly); lead and copper (once every five years); and asbestos (once every nine years).

4.2 Treatment Process Description

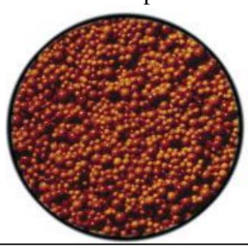
4.2.1 Technology Description. The treatment system installed at Seely-Brown Village used both ArsenX^{np} and LayneRT™ media. The performance evaluation was sub-divided into two study periods.

Study Period I took place from February 4 through December 2, 2009, using ArsenX^{np} and Study Period II followed immediately thereafter from December 3, 2009, through September 24, 2010, using LayneRT™.

Manufactured by the Purolite Company, ArsenX^{np} is an engineered hybrid inorganic/organic sorbent that incorporates a nanoparticle technology originally developed by researchers at Lehigh University in Bethlehem, PA, and further refined by SolmeteX, Inc., of Northborough, MA. The media consists of hydrous iron oxide nanoparticles impregnated into 300 to 1,200 μm anion exchange resin beads. The hybrid material contains approximately 25% of iron (dry weight) or 36% of iron oxide, Fe_2O_3. Analysis using transmission electron microscopy (TEM) indicates that hydrous iron oxide is present as 50 to 150 nm thick coating throughout the resin beads.

LayneRT™ is a newer version of hybrid adsorbent manufactured by Dow Chemical. Both media do not require backwashing, are regenerable, and are NSF International (NSF) 61 certified for use in drinking water treatment systems. Regenerated ArsenX^{np} is certified to NSF/American National Standards Institute (ANSI)-61 by the Water Quality Association. Table 4-2 summarizes physical properties, which are essentially the same for both media.

Table 4-2. Properties of ArsenX^{np} and LayneRT™ Media

Property	ArsenX^{np}	LayneRT™
Physical Form and Appearance	Reddish-brown spherical beads 	Reddish-brown spherical beads 
Particle Size (μm)	300 to 1,200	300 to 1,200
Operating Temperature (°F)	33 to 172	33 to 172
Operating pH (S.U.)	5.0 to 8.5	5.0 to 8.5
Bulk Density (g/cm^3 [lb/ft^3])	0.79 to 0.84 [49 to 52]	0.79 to 0.84 [49 to 52]
Moisture Content (%)	55–60	-
Base Polymer	Macroporous polystyrene	Macroporous polystyrene
Active Component	Hydrous iron oxide	Hydrous iron oxide

4.2.2 System Design and Treatment Process. The 15-gpm arsenic removal system installed at Seely-Brown Village consisted of a pre-filter, two adsorption vessels, and a control head assembly. The treatment system was placed upstream of the pre-existing storage tank, booster pump skid, pressure tank, and Birm filters as shown by the schematic in Figure 4-4. Table 4-3 specifies key system design parameters. Figure 4-5 presents a process flowchart along with the sampling and analysis schedule. Key process components are discussed in detail below.

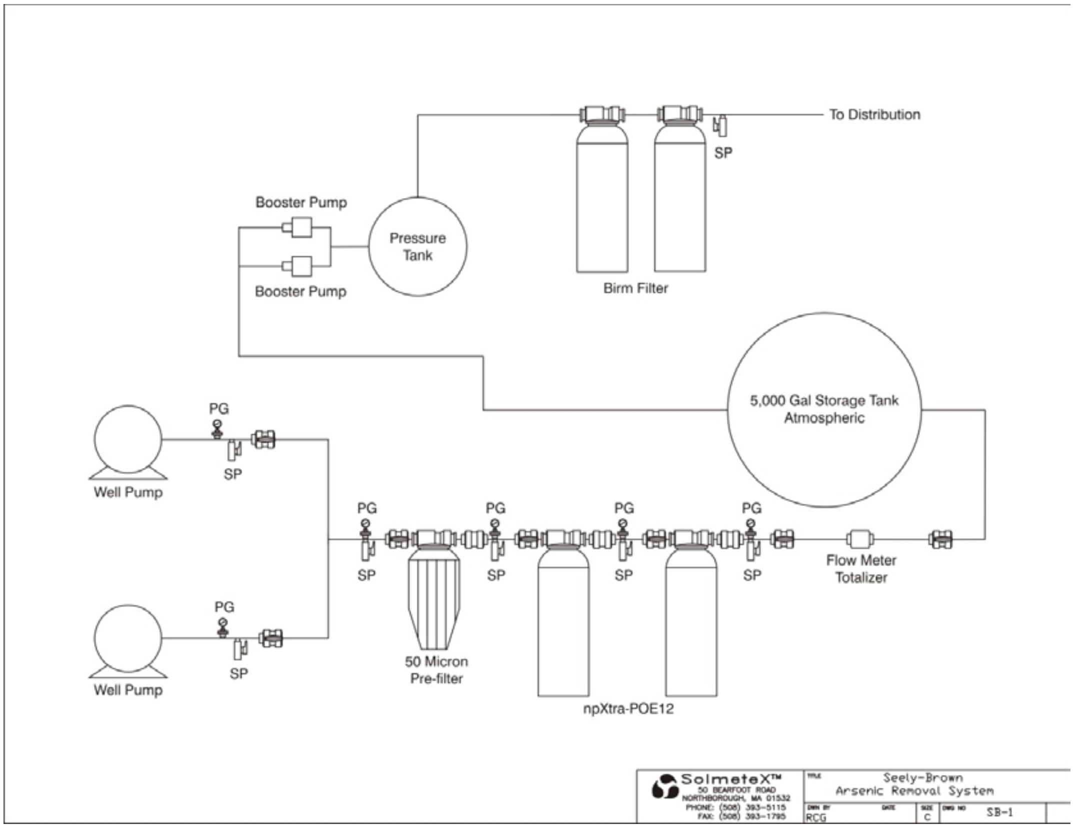


Figure 4-4. Schematic of SolmeteX's ArsenX^{np} Arsenic Removal System at Seely-Brown Village

- **Intake** – Wells No. 1 and No. 2 were originally configured to operate on an alternating basis. Because of a Connecticut DPH request to blend water from the two wells due to significantly different water quality in the two wells, the electrical panel was modified so that both wells could operate simultaneously. Raw water pumped from the two wells was combined via a T-fitting before entering a 50-µm pre-filter to remove any well sediment and particulates. The use of the pre-filter was recommended because filtered water could help minimize particulate fouling of the media beds.

- **Adsorption** – The adsorption system consisted of two 12-in × 52-in pressure vessels configured in series. The vessels were of fiberglass construction and rated for 150 psi working pressure. Each vessel contained 2.3 ft^3 of ArsenX^{np} or LayneRT™ media. Based on a design flowrate of 15 gpm, the empty bed contact time (EBCT) for each vessel was 1.2 min (or 2.3 min for both vessels) and the hydraulic loading rate was 19 gpm/ft^2. The anticipated pressure drop across a clean resin bed was approximately 10 psi. Figure 4-6 shows a schematic of the control head assembly.

  The adsorption system was designed for manual operation. The operator was required to manually open or close hand valves to achieve an intended vessel configuration and correct flow path. The operator also monitored and adjusted system flowrate and operating pressure, recorded log sheets, and took routine samples of raw water and treated water following the lead and lag vessels. All plumbing for the system was schedule 80 polyvinyl chloride (PVC) and the skidded unit was pre-plumbed with the necessary isolation valves, check valves, sampling ports, and other features.

Table 4-3. Design Features of ArsenX^{np} Adsorption System

Parameter	Value	Remarks
Influent Specifications		
Peak Flowrate (gpm)	15	–
Total Arsenic Concentration (µg/L)	≤30	Based on source water samples taken on 11/02/01 to 12/15/06
Total Iron Concentration (µg/L)	<25 to 250	
Adsorption		
No. of Vessels	2	–
Configuration	Series	–
Tank Size (in)	12 D × 52 H	–
Vessel Cross Sectional Area (ft^2)	0.79	–
Media Volume (ft^3/tank)	2.3	4.6 ft^3 total media volume in two vessels
Media Depth (in)	35	
Hydraulic Loading Rate (gpm/ft^2)	19	Based on 15 gpm flowrate
EBCT (min/tank)	1.2	Based 2.3 ft^3 of media and 15 gpm flowrate
Differential Pressure Across System (psi)	10	Across two vessels and valves
Maximum Daily Production (gpd)	21,600	Based on 15-gpm peak flowrate, 24 hr/day
Average Daily Production (gpd)	4,800	Based on 15-gpm peak flowrate and 5.3 hr/day average daily run time
Hydraulic Utilization (%)	22.2	
Projected Media Run Length to 10-µg/L As Breakthrough from Lead Vessel (BV)	45,000	Based on revised vendor run length estimate dated March 10, 2008
Throughput to 10-µg/L As Breakthrough from Lead Vessel (gal)	774,000	1 BV = 2.3 ft^3 = 17.2 gal
Projected Media Life (day)	161	Based on 4,800 gpd water usage

- **Backwash** – ArsenX^{np} and LayneRT™ media did not require backwashing during the performance evaluation study.
- **Media Rebedding** – SolmeteX initially recommended replacing spent ArsenX^{np} media in the lead vessel (Vessel A) with virgin ArsenX^{np} when total arsenic levels following the lag vessel exceeded the MCL. After rebedding, the freshly rebedded vessel would be placed in the lag position and the vessel with partially spent ArsenX^{np} would be placed in the lead position for continuing system operations. Because of the development of a new media, LayneRT™, the vendor recommended replacing the spent media in both adsorption vessels with LayneRT™. Instead of rebedding onsite, vessels filled with LayneRT™ were brought to the site by a SolmeteX technician. Upon positioning the new vessels, the old vessels with spent ArsenX^{np} were returned to a SolmeteX shop.
- **Treated Water Storage and Distribution –** After treatment for arsenic removal, the treated water was stored in a 5,000-gal atmospheric storage tank. Two skid-mounted, 1.5-hp booster pumps were used to provide pressure to the distribution system via a 300-gal hydropneumatic tank with a 70/80 psi pressure setting. The pressurized water was sent through two pre-existing Birm filters configured in parallel prior to entering the distribution system. Post-chlorination was not required at this facility.

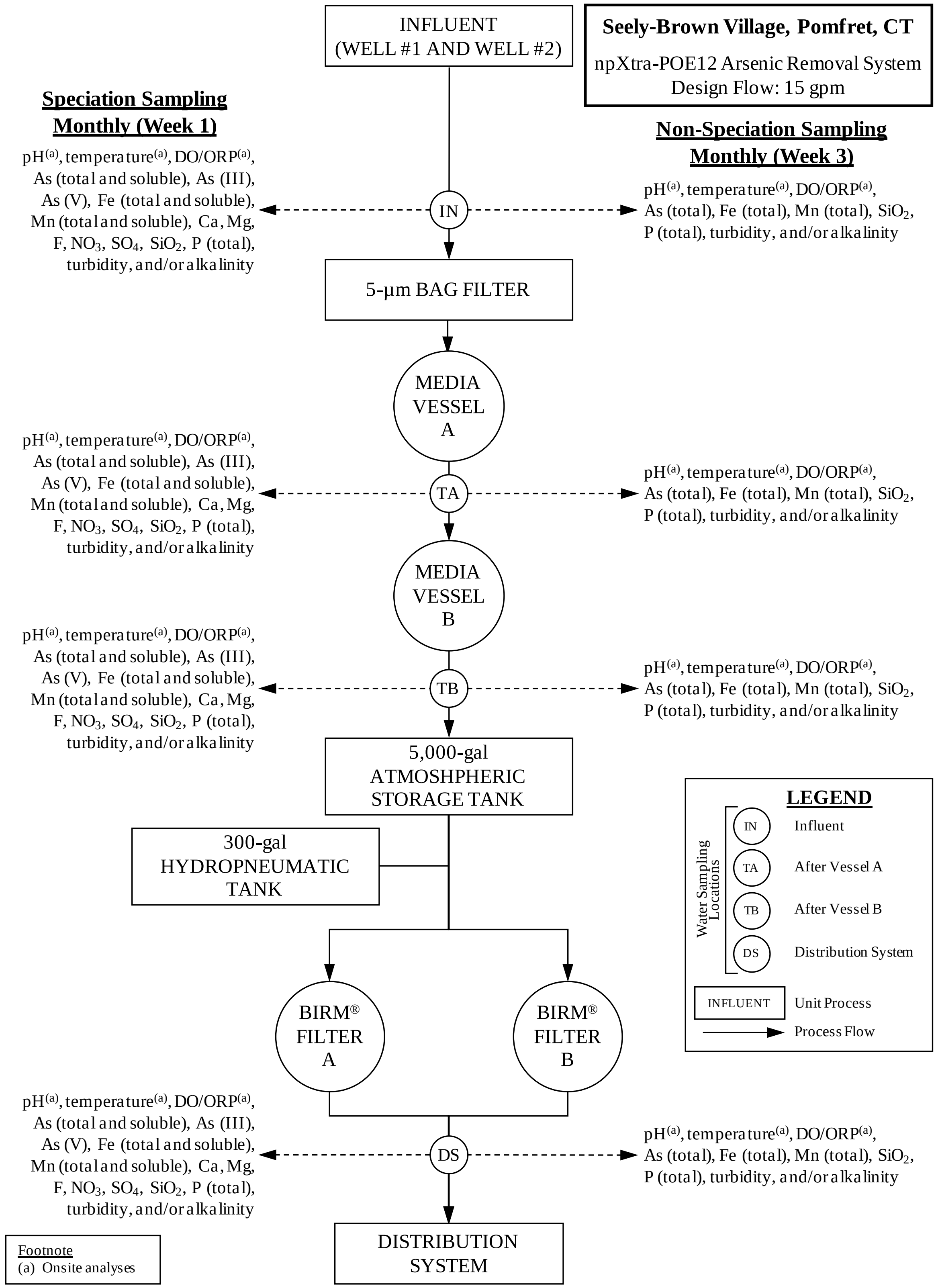


Figure 4-5. Process Flow Diagram and Planned Sampling/Analytical Schedules
(Pre-filter Nominal Pore Size Reduced from 50 to 30 µm on June 9, 2009)

ITEM	QTY	DESCRIPTION
1	2	Clack Media Column Tank Head
2	10	Adapters-WS1 Fittin X 1" NPT-M
3	4	1" PVC Female Threaded Union
4	2	Medla Column 12X52"
5	1	Control Head
6	1	Clack Bypass Valve

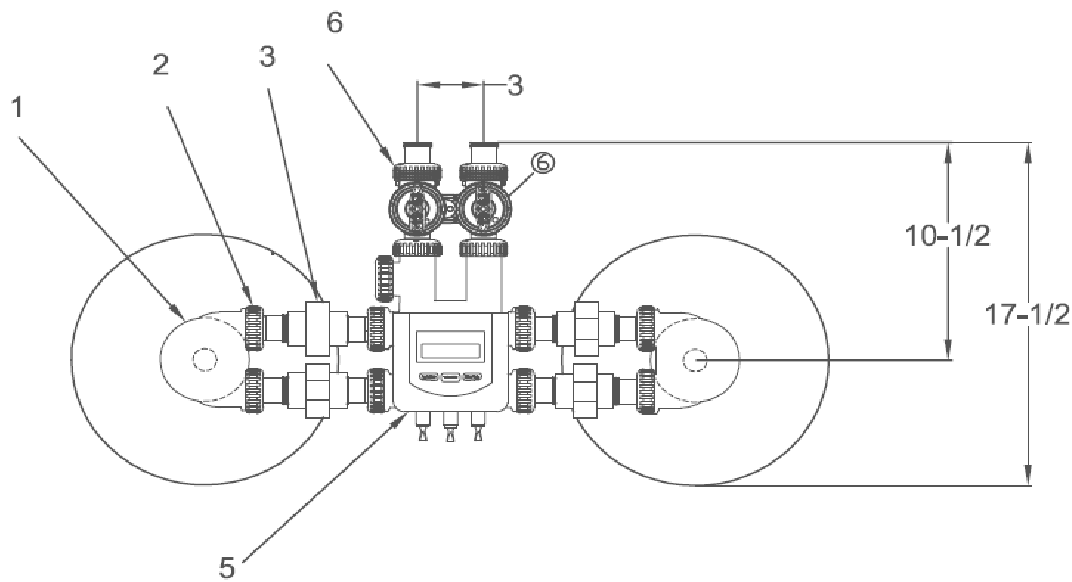


Figure 4-6. SolmeteX npXtra-POE12 Control Head Assembly

4.3 System Installation

SolmeteX completed installation and shakedown of the treatment system on January 21, 2009. The following briefly summarizes system installation activities, including permitting, system offloading, installation, shakedown, and startup.

4.3.1 Permitting. Design drawings and a process description of the proposed treatment system were submitted to Connecticut DPH by SolmeteX, on behalf of Seely-Brown Village, on May 7, 2008. In a request for additional information dated May 21, 2008, Connecticut DPH commented and recommended placement of the treatment system at the wellhead (vs. downstream of the storage tank), inclusion of an oxidation unit for soluble As(III) to soluble As(V) conversion, and relocation of the existing Birm filters to upstream of the arsenic treatment system for iron and manganese removal.

A conference call was held on August 20, 2008 with Connecticut DPH to discuss the state's requests and recommendations. As a result of the discussion, it was agreed that the treatment system would be moved to the wellhead with a total flow of 15 gpm supplied by both wells. Operating the two wells simultaneously would ensure more uniform source water quality prior to the treatment system. It also was agreed that the installation of an oxidation unit and reconfiguration of the Birm filters would be deferred because of relative low soluble As(III) (<2.5 μg/L), iron (<27 μg/L), and manganese concentrations (at <40 μg/L) in source water (see Table 4-1) and because of Connecticut DPH's position to only recommend rather than require.

SolmeteX completed all requested changes to the permit application, updated the design documents, and provided the package to Seely-Brown Village for signature and re-submission on October 27, 2008. On October 30, 2008, Seely-Brown Village mailed the signed package to Connecticut DPH. On November 26, 2008, Connecticut DPH granted a permit to Seely-Brown Village with no further comments.

4.3.2 Installation, Shakedown, and Startup. Upon receipt of the permit, Seely-Brown Village began to modify electrical wiring to allow both well pumps to operate at the same time. By January 21, 2009, all electrical wiring changes were complete and in time for system shakedown and startup.

System components were delivered to Seely-Brown Village on January 6, 2009. Installation activities, including offloading, plumbing, hydraulic testing, media loading, and disinfection were completed by January 21, 2009. All installation activities were conducted by SolmeteX and its subcontractor, Aqua Pump Co., Inc.

Before and after media loading, the system was tested hydraulically to ensure within-spec system operations. Table 4-4 presents results of the tests performed with either Well No. 1 or 2 or both wells. Before media loading with one or both wells operating, the system inlet pressure was 5 psi and pressure losses across the lead and lag vessels were 1 and 2 psi, respectively. Because no leak or excessive pressure loss was observed, media loading followed.

Table 4-4. System Hydraulic Test Results at Seely-Brown Village

Monitoring Location	System Pressure Before Media Loading			System Pressure After Media Loading		
	At 4 gpm with Well No. 1 only	At 5 gpm with Well No. 2 only	At 9 gpm[(a)] with Both Wells	At 4 gpm with Well No. 1 only	At 5 gpm with Well No. 2 only	At 9 gpm[(a)] with Both Wells
System Inlet	5	5	5	5	7	11
After Vessel A	4	4	4	4	6	10
After Vessel B	2	2	2	3	3	5
System Outlet	0	0	0	0	0	0

(a) Estimated combined flowrate due to lack of flow meter during testing.

Approximately 2.3 ft^3 of ArsenX^{np} was loaded into each adsorption vessel without the use of underbedding. A freeboard of 9 in was measured above the media bed in each vessel. This freeboard value was smaller than the would-be value of 17 in, assuming that the bed depth was 35 in. After installation, the media in each vessel was flushed with approximately 230 gal of water (i.e., 100 gal/ft^3 of media); the wastewater produced was discharged to the septic system. Sanitization of the system was accomplished by pouring approximately 4 oz (1 oz in 8 gal of water) of Sani-System into the lead vessel, applying water until both vessels had the Sani-System solution, allowing it to stand for 10 min, and then rinsing the vessels with water until they were clean.

After the system was put in the forward service mode, the system with media was tested again hydraulically. Readings of the system inlet pressure were 5, 7, and 11 psi at 4 gpm (with Well No. 1 operating only), 5 gpm (with Well No. 2 operating only), and 9 gpm (with both wells operating), respectively. Pressure losses across the lead and lag vessels ranged from 1 to 3 psi with only one well operating, and was 1 and 5 psi, respectively, with both wells operating. The 5 psi pressure loss across the lag vessel was considerably higher than that across the lead vessel, suggesting that more media flushing might be needed to remove media fines. Connecticut DPH visited the site for the final inspection on January 29, 2009, and requested that the system remain offline until negative bacteriological test results were obtained and a final approval was granted by Connecticut DPH. The system was, therefore, turned off on January 30, 2009.

On January 30, 2009, Seely-Brown Village notified Connecticut DPH of the construction completion via the "Certification of Completed Water or Treatment Works: Construction/Installation." The notification was followed with negative bacteriological test results of samples taken on January 21, 2009. Because Seely-Brown Village did not have a certified operator, it contracted with Millenium Water to retain services for system operation and collection of compliance samples by certified operators. On February 2, 2009, Seely-Brown Village submitted the "Operator Verification Form" to notify Connecticut DPH's Drinking Water Section (DWS) of the designation. On February 2, 2009, Connecticut DPH issued a copy of the Arsenic Treatment System project closure letter for Seely-Brown Village and the arsenic treatment system was officially started on February 4, 2009.

On March 11, 2009, two Battelle staff members visited Seely-Brown Village to inspect the system and provide operator training. The system was found to be installed as specified. The only punch-list item for the vendor was to provide replacement filters with a correct nominal pore size, i.e., 50 µm. A 5-µm filter bag was used during Battelle's site visit.

4.4 System Operation

4.4.1 Operational Parameters. Operational parameters for the 20-month demonstration study were tabulated and are attached as Appendix A. Table 4-5 summarizes key parameters. The system began to operate on February 4, 2009, and logging of operational data began on the same day. The operator experienced a few issues initially when using the field meter for onsite water quality measurements, but was able to perform the measurements with the assistance of the Battelle Study Lead a few months into the study.

The performance evaluation study covered two study periods with Study Period I extending from February 4 through December 2, 2009, and Study Period II from December 3, 2009, through September 24, 2010. Study Period I evaluated ArsenX^{np}; Study Period II evaluated LayneRT™.

Although Wells No. 1 and No. 2 operated simultaneously, the Well No. 1 hour meter (Figure 4-7) registered 7.5% and 8% more hours than the Well No. 2 hour meter during Study Periods I and II, respectively. The differences observed probably were due to meter calibration issues. Based on the Well No. 1 hour meter, the system operated for 1060.6 and 1,096.1 hr with daily run times averaging 3.6 and 3.7 hr/day in Study Periods I and II, respectively.

Based on readings from the two AMCO C700 totalizers (Figure 4-7) installed at the wellheads, Wells No. 1 and 2 produced 327,400 and 253,800 gal of water, respectively, during Study Period I, and 342,800 and 263,800 gal, respectively, during Study Period II. Total amounts of water produced in the two study periods were 581,200 and 606,600 gal, respectively, which were comparable to the amounts (i.e., 3.3% and 3.0% higher) registered by the two totalizers installed after the two adsorption vessels.

Flowrates calculated based on readings of the two totalizers and two hour meters installed at the wellheads averaged 5.4 and 4.4 gpm for Wells No. 1 and No. 2, respectively, in Study Period I, and 5.4 and 4.6 gpm, respectively, in Study Period II. Combined flowrates at wellheads averaged 9.8 and 10.0 gpm in Study Periods I and II, respectively. These values were every close to the respective average

Table 4-5. Summary of System Operation Parameters

Operational Parameter	Study Period I ArsenX media	Study Period II LayneRT Media
Study Duration	02/04/09–12/02/09	12/03/20–09/24/10
Total Operating Time (hr)[a]	1060.6 (Well No. 1)	1096.1 (Well No. 1)
	986.4 (Well No. 2)	1014.8 (Well No. 2)
Total Operating Days (day)	301	295
Daily Run Time (hr/day)	3.6 [0–13.5] (Well No.1)	3.7 [0–19.7] (Well No. 1)
	3.4 [1.1–10.3] (Well No. 2)	3.5 [0.9– 8.2] (Well No. 2)
Individual Well Production (gal)[b]	327,400 (Well No. 1)	342,800 (Well No. 1)
	253,800 (Well No. 2)	263,800 (Well No. 2)
	581,200 (Combined)	606,600 (Combined)
Vessel Throughput (gal)[c]	562,316 (Vessel A)	589,139 (Vessel A)
	562,171 (Vessel B)	589,139 (Vessel B)
Calculated Well Flowrate (gpm)[d,e]	5.4 [0.7–11.9] (Well No. 1)	5.4 [2.4–8.7] (Well No. 1)
	4.4 [1.6–19.4] (Well No. 2)	4.6 [1.8–18.2] (Well No. 2)
	9.8 [4.5–22] (Combined)	10.0 [7.1–24.0] (Combined)
Instantaneous Flowrate (gpm)[f]	9.4 [6.6–10]	9.6 [6.3–10.2]
EBCT (min/vessel)[c]	1.8 [2.6–1.7]	1.8 [2.7–1.7]
Hydraulic Loading Rate (gpm/ft^2)	11.9 [8.4–12.7]	12.2 [8.0–12.9]
Pressure at Wellhead (psi)	37 [18–60] (Well No. 1)	37 [10–55] (Well No. 1)
	38 [17–60] (Well No. 2)	38 [13–55] (Well No. 2)
Pressure Before Pre-filter (psi)[g]	35 [15–44] (50 µm filter)	36 [19–50] (30 µm filter)
	36 [30–60] (30 µm filter)	
Pressure After Pre-filter (psi)[g]	28 [14–32] (50 µm filter)	31 [15–40] (30 µm filter)
	31 [25–35] (30 µm filter)	
Pressure After Vessel A (psi)	20 [10–30]	21 [10–25]
Pressure After Vessel B (psi)	12 [3–14]	15 [7–18]
Δp Across Vessel A (psi)	10 [4–13]	10 [5–20]
Δp Across Vessel B (psi)	8 [4–17]	7 [3–9]
Δp Across System (psi)	23 [9–50]	22 [12–40]

(a) Based on hour meters installed at respective well heads.
(b) Based on totalizers installed at respective wellheads.
(c) Based on totalizer installed after respective vessels.
(d) Based on readings of respective wellhead totalizers and hour meters.
(e) After omitting obvious outliers.
(f) Based on flow meter installed after Vessel B.
(g) Pre-filter nominal pore size reduced from 50 to 30 µm on 06/09/09.

instantaneous flowrate readings, i.e., 9.4 and 9.6 gpm, registered by a GPI turbine flow meter installed after Vessel B in the two study periods.

After water was combined, it flowed through a 30-µm pre filter (Figure 4-8) before entering Vessels A and B. Initially, 50-µm filters were used, but the nominal pore size of the filters was reduced to 30 µm on June 9, 2009, as an attempt to capture more solids.

Based on 2.3 ft^3 (or 17.2 gal) of media in each vessel and instantaneous flowrates, the average EBCT was 1.8 min/vessel for both study periods, compared to the design value of 1.2 min/vessel. Average hydraulic loading rates were 11.9 and 12.2 gpm/ft^2 in Study Periods I and II, respectively, compared to the design value of 19 gpm/ft^2.

Figure 4-7. Wellhead Totalizers and Hour Meters

Figure 4.8. Pre-filter and Adsorption Vessels at Seely-Brown Village

Pressure readings were monitored at both wellheads, before pre-filter, before Vessels A and B, and after Vessels A and B. Due to accumulation of sediment and particulate in the pre-filter, pressure readings before the filter rose significantly from an average baseline level of approximately 30 psi (i.e., pressure after filter) to as high as 60 psi, depending upon the nominal pore size of the filter used and frequency of filter replacement. As shown in Figure 4-9, the pressure loss (Δp) across the pre-filter immediately after system startup on February 4, 2009, was 1 psi. Pressure losses across the filter increased steadily to 17 psi by April 14, 2009, approximately 10 weeks into system operation. Immediately after replacement of the pre-filter on April 15, 2009, pressure before the pre-filter returned to the baseline level of 30 psi and Δp across the filter returned to 0 psi. After approximately 8 weeks of follow-on system operation, Δp across the filter increased to 17 psi again. To capture more solids and to ensure proper system operation, the vendor recommended the use of 30-µm pre-filters with a more frequent filter replacement schedule of once every two weeks. This was implemented during a site visit by the vendor on June 9, 2009.

Since the use of 30-µm filters, inlet pressure readings to the filter increased much more quickly from an average baseline level of approximately 33 psi to significantly elevated levels, as reflected by most of the spikes shown in Figure 4-9. The rapid rises of inlet pressure and Δp occurred even with more frequent filter replacements, i.e., once every 11 to 45 days (or 25 days [on average]). From June 10 through September 2, 2009, however, inlet pressure readings remained uncharacteristically low at mid-30 psi levels, even though the pre-filter had been replaced only once on August 24, 2009. The only plausible explanation for this would be that fewer particles were present in incoming source water, thus resulting in little or no solid buildup in the pre-filter. Careful examination of analytical data in Appendix B revealed that source water samples collected during this period contained only low levels of iron and manganese, i.e., 42 and 28, µg/L [on average], respectively, present primarily as particulate. In contrast, as much as 1,232 and 581 µg/L of iron and manganese, respectively, were measured in Study Period I and 1,054 and 709 µg/L in Study Period II, with most existing also in the particulate form. Occurrence of particulate iron and manganese in source water appeared to be rather sporadic as discussed in Section 4.5.1.

Because of the presence of particulate iron and manganese in source water and because of the need for rather frequent replacement of pre-filters, it would be prudent for the facility to consider replacing the current pre-filter with a relatively larger bag filter for more sustainable system operation. The facility also could consider repositioning the Birm filters from its current location, i.e., after the 5,000-gal atmospheric storage tank and 300-gal hydropneumatic tank, to upstream of the arsenic treatment system, as recommended previously by Connecticut DPH. In doing so, the Birm filters can precipitate any soluble iron and manganese and filter out most, if not all, iron and manganese particulate before water flows into the arsenic treatment system. Birm media has been shown to be effective in oxidizing soluble iron and manganese and removing iron and manganese particulate.

As shown in Table 4-5, the average pressure after the 50-µm pre-filter was 28 psi; the average pressure after the 30-µm pre-filter was 31 psi. After Vessels A and B, average pressure readings were reduced to 20 and 12 psi, respectively, in Study Period I, and to 21 and 15, respectively, in Study Period II. As such, an average of 10 and 8 psi pressure loss was realized across Vessels A and B, respectively, in Study Period I, and 10 and 7 psi, respectively, in Study Period II. The average pressure loss across the system was 23 psi in Study Period I and 22 psi in Study Period II. Pressure losses across the two adsorption vessels and the system were rather constant as shown in Figure 4-9.

4.4.2 Media Replacement. SolmeteX estimated a media life of 45,000 BV for ArsenX^{np} before reaching 10-µg/L arsenic breakthrough from the lead vessel. At an average daily use rate of 4,800 gal, this corresponded to approximately 161 days of system operations. Actual media replacement would not occur until arsenic concentrations following the lag vessel had reached 10 µg/L or the media in the lead vessel had been fully exhausted, whichever happened first. The vessel containing freshly rebedded ArsenX^{np} would be placed in the lag position and the vessel containing partially spent media would be

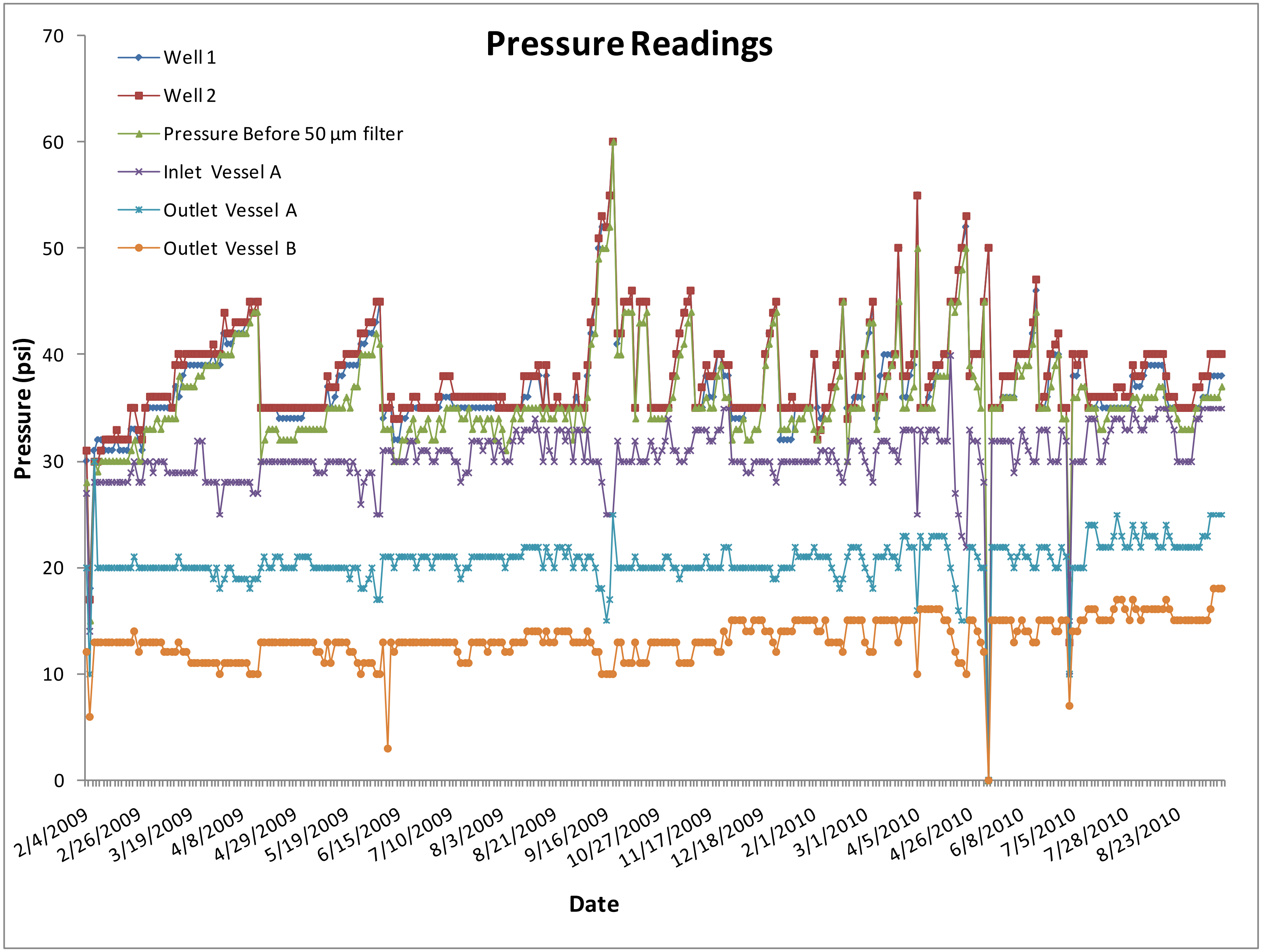


Figure 4-9. Pressure Readings Across Treatment Train

placed in the lead position for continuing system operations. Although ArsenX^{np} could be regenerated, its regeneration was never considered due to the small size of the treatment system. Also, because ArsenX^{np} was no longer available on the marketplace when the system was ready for rebedding, LayneRT™ was recommended to Battelle and Seely-Brown Village by the vendor.

On December 3, 2009, two vessels each containing 2.3 ft^3 of LayneRT™ were brought to the site to replace the vessels containing spent ArsenX^{np}. After sanitization, the vessels were put online for continuing system operations. The vessels containing spent ArsenX^{np} were returned to the vendor's shop.

4.4.3 Residual Management. Residuals included spent filter bags and spent media. The spent filter bags were disposed of with landfill trash. The spent media was regenerated with other spent media from the vendor's point-of-entry product line and used in non-drinking water applications. The vessels were disposed of because they could not be reused according to the vendor.

4.4.4 System/Operation Reliability and Simplicity. Once the system was installed there were no operational issues affecting the system. The system O&M and operator skill requirements are discussed below in relation to pre- and post-treatment requirements, levels of system automation, operator skill requirements, preventative maintenance activities, and frequency of chemical/media handling and inventory requirements.

Pre- and Post-Treatment Requirements. No pretreatment was required, but raw water from the wells passed through a 50- or 30-µm filter cartridge located upstream of the treatment system to remove sediment and particulates. Filters were changed biweekly to monthly to ensure that pressure losses across the filter cartridge were kept below 10 psi. However, due to untimely changes of filters, the system experienced elevated pressure losses (i.e., >10 psi) a number of times during the study period.

System Automation. The adsorption system was designed for manual operation. The operator had to manually open or close hand valves to achieve an intended vessel configuration and correct flow path. The on/off of the well pumps was controlled by the low/high level sensors in the 5,000-gal atmospheric storage tank. Water in the storage tank was pumped by two 1.5-hp booster pumps to replenish the 300-gal hydropneumatic tank prior to entering the distribution system. The on/off of the booster pumps was controlled by a 70/80 psi pressure setting in the hydropneumatic tank.

Operator Skill Requirements. Under normal operating conditions, skills required to operate the arsenic treatment system were minimal. Operator's duties were to visually inspect the system and record operational data during system operations.

Seely-Brown Village is a community water system. According to Connecticut DPH, all community and non-transient, non-community water systems are required to have their water treatment plants, distribution systems, and small water systems operated by certified operators. To be certified as a water treatment plant operator, a person must demonstrate the ability to responsibly operate a plant of a given classification applied for (i.e., I, II, Ill, IV) by passing a written examination. The minimum education requirement is either a high school diploma or a high school equivalency diploma. Any amount of educational training beyond high school (12 years) in a field of study applicable to water treatment may be substituted for an equal amount of the experience requirement; however, one year of experience is required for all classes. Experience in class means experience gained in operating a particular class plant or the next lower class providing that the operator has direct responsible charge. Operators must renew their certificates every three years by meeting specific training hour requirements for renewal. The Seely-Brown Village operator has a Class II certification.

4.5 System Performance

4.5.1 Treatment Plant Sampling. In Study Period I, treatment plant water samples were collected on 22 occasions (including two duplicate samples collected during two non-speciation sampling events) with field speciation performed during 10 of the 22 occasions at IN, TA, TB, and DS sampling locations. In Study Period II, treatment plant water samples were collected on 18 occasions, including two duplicate samples collected during two non-speciation sampling events, with field speciation performed during 10 of the 18 occasions at the same four sampling locations. Table 4-6 summarizes analytical results of arsenic, iron, and manganese obtained in both study periods. Table 4-7 summarizes results of other water quality parameters. Study Period II results are bracketed in both tables for side-by-side comparison with Study Period I results. Appendix A contains a complete set of analytical results collected throughout the performance evaluation study.

Arsenic. Total arsenic concentrations in source water ranged from 22.4 to 29.4 µg/L and averaged 25.2 µg/L in Study Period I; and ranged from 17.2 to 34.4 µg/L and averaged 25.1 µg/L in Study Period II. Based on the 20 speciation sampling events in both study periods (see bar charts in Figures 4-10 and 4-11), soluble As(V) was the predominating species, ranging from 17.1 to 25.4 µg/L and averaging 20.7 µg/L in Study Period I and from 15.5 to 24.7 µg/L and averaging 21.8 µg/L in Study Period II. The presence of As(V) as the predominating species was consistent with somewhat elevated DO levels and high ORP readings (i.e., 2.8 mg/L and 444 mV [on average], respectively). Only two and three sets of DO and ORP measurements, respectively, were made during the entire study period due to malfunctioning of field handheld probes and difficulties in handling these probes by the operator.

Low levels of soluble As(III) also existed, with concentrations ranging from <0.1 to 5.7 µg/L and averaging 3.2 µg/L in Study Period I and from <0.1 to 5.9 µg/L and averaging 1.6 µg/L in Study Period II. Particulate arsenic concentrations were low as well, averaging 0.8 µg/L in Study Period I and 0.2 µg/L in Study Period II. Arsenic concentrations in source water measured during the performance evaluation study were consistent with those collected previously from Wells No. 1 and No. 2 during source water sampling (Table 4-1).

As shown by the second and the third bar charts in Figures 4-10 and 4-11, both soluble As (V) and soluble As (III) could be removed by ArsenX and LayneRT™. However, after treating approximately 260,000 to 275,000 gal (or 15,100 to 16,000 BV) of water (1 BV = 2.3 ft^3 [or 17.2 gal] of media in the lead vessel), arsenic concentrations following the lead vessel had already reached 10 µg/L for both $ArsenX^{np}$ and LayneRT™ media. Arsenic breakthrough at 10 µg/L following the lag vessel occurred at approximately 15,000 BV for $ArsenX^{np}$ or at >18,000 BV for LayneRT™ (at 17,900 BV, the arsenic level was 8.5 µg/L). BV calculations for the lag vessel were based on 4.6 ft^3 (or 34.4 gal) of media in both vessels. Figures 4-12 and 4-13 presents arsenic breakthrough curves for both media.

The arsenic breakthrough data indicate that the run length for $ArsenX^{np}$ is approximately 15,000 BV and that the run length for LayneRT™ is approximately 20% longer. These run length values were much shorter than the vendor-projected run length of 45,000 BV for $ArsenX^{np}$ media.

A number of water quality parameters potentially could affect media run lengths, including pH, silica, and phosphorus. pH values of raw water ranged from 7.8 to 8.0 and averaged 7.9, which were similar to those measured historically by the facility (Table 4-1). Although at the higher end of the commonly accepted range of 5.5 to 8.5, these pH values should not be a major factor impeding arsenic adsorption. Elevated silica concentrations were reported to affect arsenic removal by iron-based media (Cumming et al., 2009); however, reported concentration ranges were much higher than the one observed at Seely-Brown Village, i.e., 13.8 to 16.6 mg/L (as SiO_2). Phosphorus concentrations in raw water ranged from 130 to 298 µg/L,

Table 4-6. Summary of Arsenic, Iron, and Manganese Analytical Results

Parameter	Sampling Location	Sample Count	Concentration (µg/L) Minimum	Maximum	Average	Standard Deviation
As (total)	IN	22 [18]	22.4 [17.2]	29.4 [34.4]	25.2 [25.1]	1.9 [3.5]
	TA	22 [18]	1.0 [0.3]	21.8 [24.4]	-[(a)] [-[(a)]]	-[(a)] [-[(a)]]
	TB	22 [18]	<0.1 [<0.1]	13.4 [8.5]	-[(a)] [-[(a)]]	-[(a)] [-[(a)]]
	DS	22 [18]	<0.1 [0.4]	12.3 [27.2]	3.8 [3.0]	3.6 [6.2]
As (soluble)	IN	10 [9[(b)]]	22.5 [17.3]	26.9 [25.6]	23.9 [23.7]	1.3 [2.6]
	TA	10 [10]	1.0 [1.2]	19.3 [19.5]	-[(a)] [-[(a)]]	-[(a)] [-[(a)]]
	TB	10 [10]	<0.1 [1.3]	12.5 [19.5]	-[(a)] [-[(a)]]	-[(a)] [-[(a)]]
	DS	10 [10]	<0.1 [0.7]	11.2 [21.8]	3.8 [4.4]	3.7 [6.4]
As (particulate)	IN	10 [9[(c)]]	<0.1 [<0.1]	4.9 [0.5]	0.8 [0.2]	1.5 [0.2]
	TA	10 [10[(d)]]	<0.1 [<0.1]	0.7 [0.3]	-[(a)] [-[(a)]]	-[(a)] [-[(a)]]
	TB	10 [10]	<0.1 [<0.1]	0.3 [0.3]	-[(a)] [-[(a)]]	-[(a)] [-[(a)]]
	DS	10 [10]	<0.1 [<0.1]	0.2 [5.4]	<0.1 [0.8]	0.1 [1.8]
As (III)	IN	10 [10]	<0.1 [<0.1]	5.7 [5.9]	3.2 [1.6]	2.0 [1.6]
	TA	10 [10]	<0.1 [<0.1]	0.9 [1.0]	-[(a)] [-[(a)]]	-[(a)] [-[(a)]]
	TB	10 [10]	<0.1 [<0.1]	0.4 [0.7]	-[(a)] [-[(a)]]	-[(a)] [-[(a)]]
	DS	10 [10]	<0.1 [<0.1]	0.3 [0.7]	0.1 [0.2]	0.1 [0.2]
As (V)	IN	10 [9[(e)]]	17.1 [15.5]	25.4 [24.7]	20.7 [21.8]	2.7 [3.0]
	TA	10 [10]	0.1 [0.2]	19.1 [19.4]	-[(a)] [-[(a)]]	-[(a)] [-[(a)]]
	TB	10 [10]	<0.1 [<0.1]	12.2 [8.0]	-[(a)] [-[(a)]]	-[(a)] [-[(a)]]
	DS	10 [10]	<0.1 [0.6]	11.0 [21.1]	3.7 [4.2]	3.7 [6.2]
Fe (total)	IN	21 [18]	<25 [<25]	1,232 [1,054]	97.3 [146]	256 [260]
	TA	22 [18]	<25 [<25]	<25 [<25]	<25 [<25]	- [-]
	TB	22 [18]	<25 [<25]	<25 [<25]	<25 [<25]	- [-]
	DS	22 [18]	<25 [<25]	<25 [49]	<25 [<25]	- [8.6]
Fe (soluble)	IN	10 [10]	<25 [<25]	<25 [<25]	<25 [<25]	- [-]
	TA	10 [10]	<25 [<25]	<25 [<25]	<25 [<25]	- [-]
	TB	10 [10]	<25 [<25]	<25 [<25]	<25 [<25]	- [-]
	DS	10 [10]	<25 [<25]	<25 [<25]	<25 [<25]	- [-]
Mn (total)	IN	22 [18]	16.7 [14.8]	581 [709]	56.8 [104]	119 [173]
	TA	22 [18]	<0.1 [0.1]	12.0 [7.0]	2.4 [1.3]	3.4 [1.7]
	TB	22 [18]	<0.1 [<0.1]	3.3 [0.5]	0.8 [0.2]	0.8 [0.2]
	DS	22 [18]	<0.1 [<0.1]	2.4 [1.6]	0.6 [0.4]	0.6 [0.4]
Mn (soluble)	IN	10 [10]	3.6 [0.3]	11.4 [12.1]	8.1 [7.2]	2.4 [3.3]
	TA	10 [10]	<0.1 [<0.1]	1.6 [6.9]	0.4 [0.8]	0.5 [2.1]
	TB	10 [10]	<0.1 [<0.1]	0.9 [0.2]	0.4 [<0.1]	0.3 [0.0]
	DS	10 [10]	<0.1 [<0.1]	0.4 [3.8]	0.2 [0.6]	0.1 [1.1]
Ti (total)	IN	NA [3]	NA [1.8]	NA [2.6]	NA [2.2]	NA [0.4]
	TA	NA [3]	NA [1.4]	NA [1.8]	NA [1.7]	NA [0.2]
	TB	NA [3]	NA [1.0]	NA [1.7]	NA [1.3]	NA [0.3]
	DS	NA [3]	NA [1.0]	NA [1.8]	NA [1.4]	NA [0.4]

(a) Statistics not meaningful for concentrations related to breakthrough; see Figures 4-10 and 4-13 and Appendix B for results.
(b) One outlier (i.e., 0.1 µg/L) on 12/16/09 omitted.
(c) One outlier (i.e., 24.1 µg/L) on 12/16/09 omitted.
(d) One outlier (i.e., 23.2 µg/L) on 12/16/09 omitted.
(e) One outlier (i.e., 0.05 µg/L) on 12/16/09 omitted.
NA = not available
[ ] = Study Period II

Table 4-7. Summary of Other Water Quality Parameter Results

Parameter	Sampling Location	Unit	Sample Count	Concentration			Standard Deviation
				Minimum	Maximum	Average	
Alkalinity (as $CaCO_3$)	IN	mg/L	22 [15]	46.2 [46.8]	56.7 [64.4]	50.6 [53.3]	2.8 [4.4]
	TA	mg/L	22 [15]	45.0 [46.8]	53.9 [62.6]	49.3 [51.6]	2.0 [4.2]
	TB	mg/L	22 [15]	44.3 [46.5]	54.4 [61.9]	50.2 [51.8]	2.3 [3.6]
	DS	mg/L	22 [14]	46.9 [48.9]	55.6 [55.7]	50.3 [52.2]	2.3 [1.9]
Fluoride	IN	mg/L	10 [7]	0.2 [0.2]	0.3 [0.7]	0.2 [0.3]	0.0 [0.2]
	TA	mg/L	10 [7]	0.2 [0.2]	0.3 [0.3]	0.3 [0.3]	0.0 [0.0]
	TB	mg/L	10 [7]	0.2 [0.2]	0.4 [0.7]	0.3 [0.3]	0.1 [0.2]
	DS	mg/L	10 [7]	0.2 [0.2]	0.4 [0.4]	0.3 [0.3]	0.1 [0.1]
Sulfate	IN	mg/L	10 [7]	17.9 [19.5]	25.4 [25.5]	20.5 [21.5]	2.0 [1.9]
	TA	mg/L	10 [7]	19.6 [18.7]	21.1 [21.7]	20.3 [20.6]	0.5 [1.0]
	TB	mg/L	10 [7]	19.5 [19.7]	23.2 [27.2]	20.9 [21.7]	1.0 [2.6]
	DS	mg/L	10 [7]	18.8 [18.8]	21.9 [444.6]	20.5 [24.2]	1.0 [9.2]
Nitrate (as N)	IN	mg/L	10 [7]	<0.05 [<0.05]	<0.05 [<0.05]	<0.05 [<0.05]	- [-]
	TA	mg/L	10 [7]	<0.05 [<0.05]	<0.05 [<0.05]	<0.05 [<0.05]	- [-]
	TB	mg/L	10 [7]	<0.05 [<0.05]	<0.05 [<0.05]	<0.05 [<0.05]	- [-]
	DS	mg/L	10 [7]	<0.05 [<0.05]	0.1 [<0.05]	<0.05 [<0.05]	<0.05 [-]
Phosphorus (as P)	IN	μg/L	22 [17]	133 [130]	272 [298]	180 [171]	33.4 [39.5]
	TA	μg/L	22 [18]	<10 [<10]	252 [186]	-[a] [-[a]]	-[a] [-[a]]
	TB	μg/L	22 [18]	<10 [<10]	228 [224]	-[a] [-[a]]	-[a] [-[a]]
	DS	μg/L	22 [18]	<10 [<10]	183 [161]	125 [79.0]	60.4 [64.3]
Silica (as SiO_2)	IN	mg/L	22 [15]	13.8 [14.0]	16.6 [15.9]	15.1 [15.0]	0.8 [0.7]
	TA	mg/L	22 [15]	13.5 [13.7]	16.2 [16.6]	15.0 [15.0]	0.8 [0.8]
	TB	mg/L	22 [15]	13.7 [11.6]	16.5 [16.5]	15.2 [14.9]	0.7 [1.2]
	DS	mg/L	22 [14]	13.3 [9.9]	16.1 [16.1]	15.0 [14.7]	0.7 [1.5]
Turbidity	IN	NTU	22 [15]	0.3 [0.7]	6.2 [5.4]	2.0 [1.9]	1.5 [1.2]
	TA	NTU	22 [15]	0.1 [0.3]	4.2 [3.4]	1.0 [1.1]	0.9 [0.8]
	TB	NTU	22 [15]	0.1 [0.3]	5.0 [3.5]	1.1 [1.0]	1.1 [0.8]
	DS	NTU	22 [14]	<0.1 [0.2]	2.6 [1.1]	0.6 [0.4]	0.7 [0.3]
pH	IN	S.U.	4	7.8	8.0	7.9	0.1
	TA	S.U.	4	7.8	8.0	7.9	0.1
	TB	S.U.	4	7.5	8.0	7.8	0.2
	DS	S.U.	5	7.6	8.2	7.9	0.2
Temperature	IN	°C	2[a]	18.5	20.5	19.5	1.4
	TA	°C	2[b]	10.3	20.3	15.3	7.1
	TB	°C	2[c]	17.9	20.4	19.2	1.8
	DS	°C	2[d]	18.9	20.9	19.9	1.4
Dissolved Oxygen (DO)	IN	mg/L	2	2.8	2.8	2.8	0.0
	TA	mg/L	2	2.0	2.7	2.4	0.5
	TB	mg/L	2	2.0	2.6	2.3	0.4
	DS	mg/L	2	3.5	4.1	3.8	0.4
Oxidation-Reduction Potential (ORP)	IN	mV	3	414	488	444	38.9
	TA	mV	3	409	451	428	21.1
	TB	mV	3	426	451	438	12.4
	DS	mV	3	414	456	438	21.4
Total Hardness (as $CaCO_3$)	IN	mg/L	10 [7]	41.2 [49.8]	65.5 [59.9]	56.6 [56.2]	7.7 [3.4]
	TA	mg/L	10 [7]	43.8 [52.2]	72.5 [66.0]	58.2 [57.8]	8.3 [4.8]
	TB	mg/L	10 [7]	45.9 [49.8]	71.6 [69.7]	58.8 [59.5]	7.7 [7.2]
	DS	mg/L	10 [7]	44.5 [51.9]	75.7 [62.9]	58.3 [57.1]	9.1 [4.1]

Table 4-7. Summary of Other Water Quality Parameter Results (Continued)

Parameter	Sampling Location	Unit	Sample Count	Concentration Minimum	Maximum	Average	Standard Deviation
Ca Hardness (as $CaCO_3$)	IN	mg/L	11 [7]	34.8 [42.2]	55.9 [52.4]	49.0 [47.8]	7.2 [3.3]
	TA	mg/L	11 [7]	37.1 [44.4]	63.8 [56.1]	50.3 [49.0]	7.9 [4.2]
	TB	mg/L	11 [7]	38.7 [42.5]	62.9 [61.5]	50.7 [51.0]	7.5 [6.8]
	DS	mg/L	11 [7]	37.4 [44.2]	66.5 [54.7]	50.5 [48.5]	8.6 [3.9]
Mg Hardness (as $CaCO_3$)	IN	mg/L	10 [7]	6.4 [7.1]	11.9 [9.5]	8.4 [8.4]	1.7 [0.9]
	TA	mg/L	10 [7]	6.7 [7.7]	13.0 [9.9]	8.6 [8.8]	2.0 [0.7]
	TB	mg/L	10 [7]	7.2 [7.3]	13.6 [10.1]	8.9 [8.6]	2.1 [0.8]
	DS	mg/L	10 [7]	7.1 [7.7]	12.0 [9.3]	8.6 [8.6]	1.6 [0.6]

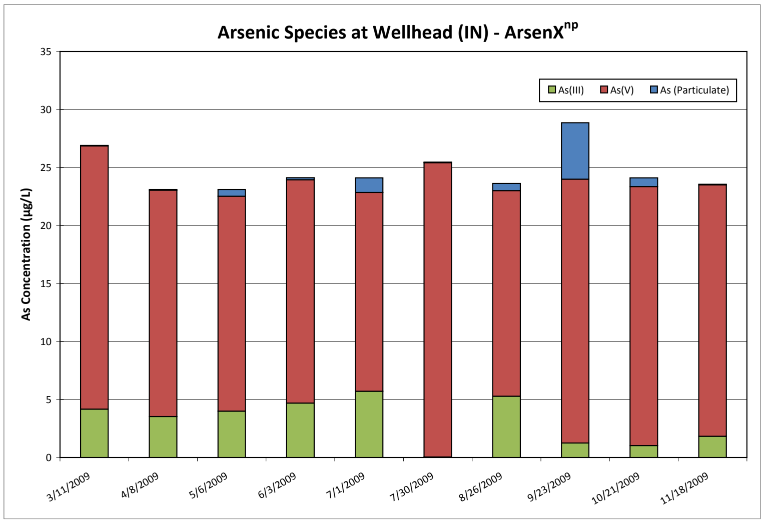
(a) Statistics not meaningful for concentrations related to breakthrough; see Figures 4-14 and 4-15 and Appendix B for results.
(b) One outlier (i.e., 25. °C mg/L) on 06/08/09 was omitted.
(c) One outlier (i.e., 25.0 °C mg/L) on 06/08/09 was omitted.
(d) One outlier (i.e., 25.0 °C mg/L) on 06/08/09 was omitted.
(e) One outlier (i.e., 25.0 °C mg/L) on 06/08/09 was omitted.
[ ] = Study Period II

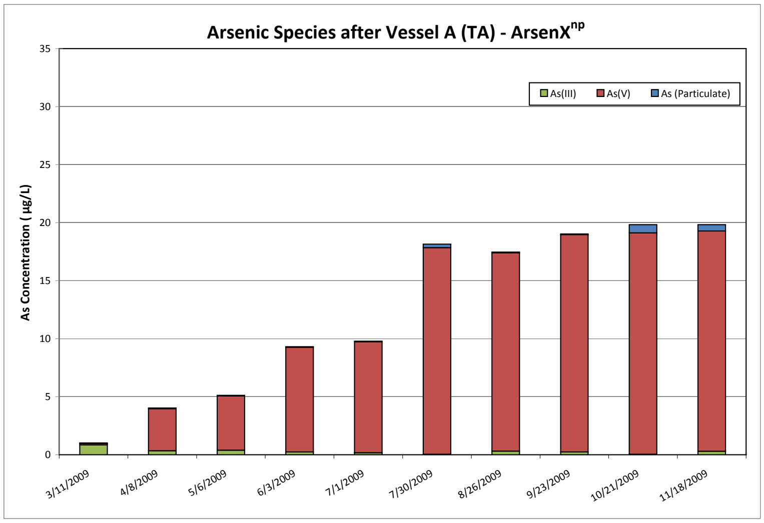
and averaged 176 µg/L. Phosphorus was completely removed by LayneRT™ during the first 5,000 BV (1 BV = 2.3 ft^3 = 17.2 gal) of system operations and began to break through thereafter. Phosphorus concentrations in system effluent started to approach influent levels at approximately 8,500 BV. Adsorption of phosphorus apparently used up some adsorptive sites, thus reducing media run lengths for arsenic. Figures 4-14 and 4-15 present phosphorus breakthrough curves.

Under a normal lead/lag arrangement, when the arsenic level following the lag vessel has reached 10 µg/L, the lag vessel is to be placed in the lead position along with a newly rebedded vessel placed in the lag position. The lead vessel with the partially spent media will last for no more than 18,000 BV (1 BV = 2.3 ft^3 = 17.2 gal), based on the breakthrough curves in Figure 4-13, before the arsenic level following the lag vessel reaches 10 µg/L again. By continuing rebedding of the lead vessel and switching the vessel position, the capacity of the media can be utilized to its greatest extent. The treatment system at Seely-Brown Village can be operated in this manner should the facility choose to continue using LanyeRT™ as the media of choice.

Iron and Manganese. Iron and manganese concentrations in raw water were mostly low, either below the MDL of 25 µg/L for iron or averaging 28.3 (in Study Period I) and 27.2 µg/L (in Study Period II) for manganese, excluding outliers. There were instances where elevated iron and manganese were observed. In Study Period I, one elevated iron (at 1,232 µg/L on September 23, 2009) and two elevated manganese levels (at 102 and 581 µg/L on September 9 and 23, 2009, respectively) were measured, existing either entirely (for iron) or mostly (for manganese) as particulates. In Study Period II, five sets of elevated iron and manganese levels were measured on February 3 (including one set of duplicate results), April 1, June 10, and October 7, 2010, with iron levels ranging from 170 to 1,054 µg/L and manganese levels ranging from 91.7 to 709 µg/L. Similar to Period Study I, iron and manganese existed either entirely (for iron) or mostly (for manganese) as particulates.

The presence of iron and manganese particulates in raw water had caused rising pressure drops across the pre-filter, prompting the vendor to recommend more frequent replacement of filters (from monthly to biweekly) as discussed in Sections 4.4.1 and 4.4.4. Some iron and manganese particulates apparently had penetrated through the filters (with a nominal pore size of 50 and 5 µm before and after June 9, 2009), as evidenced by black coatings on some ArsenX^{np} media beads observed during media changeout. Coatings on media beads could result in unwanted media fouling and shorter run length according to the vendor.





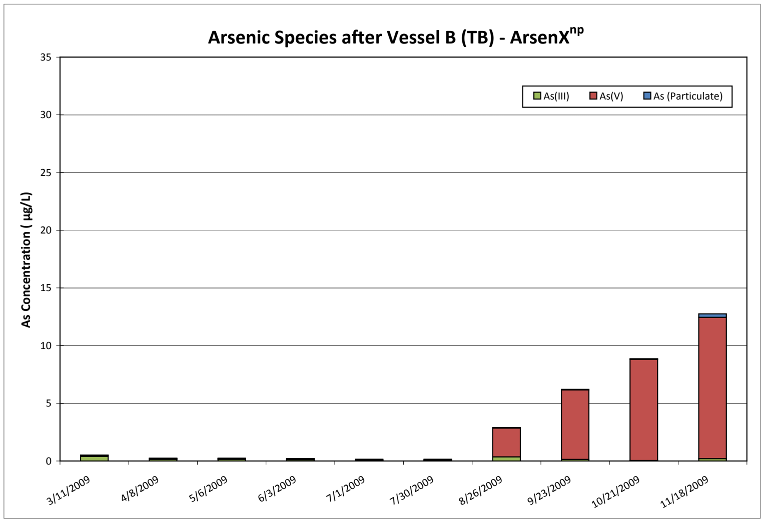


Figure 4-10. Arsenic Species at IN, TA and TB Sampling Locations with ArsenX^{np} Media

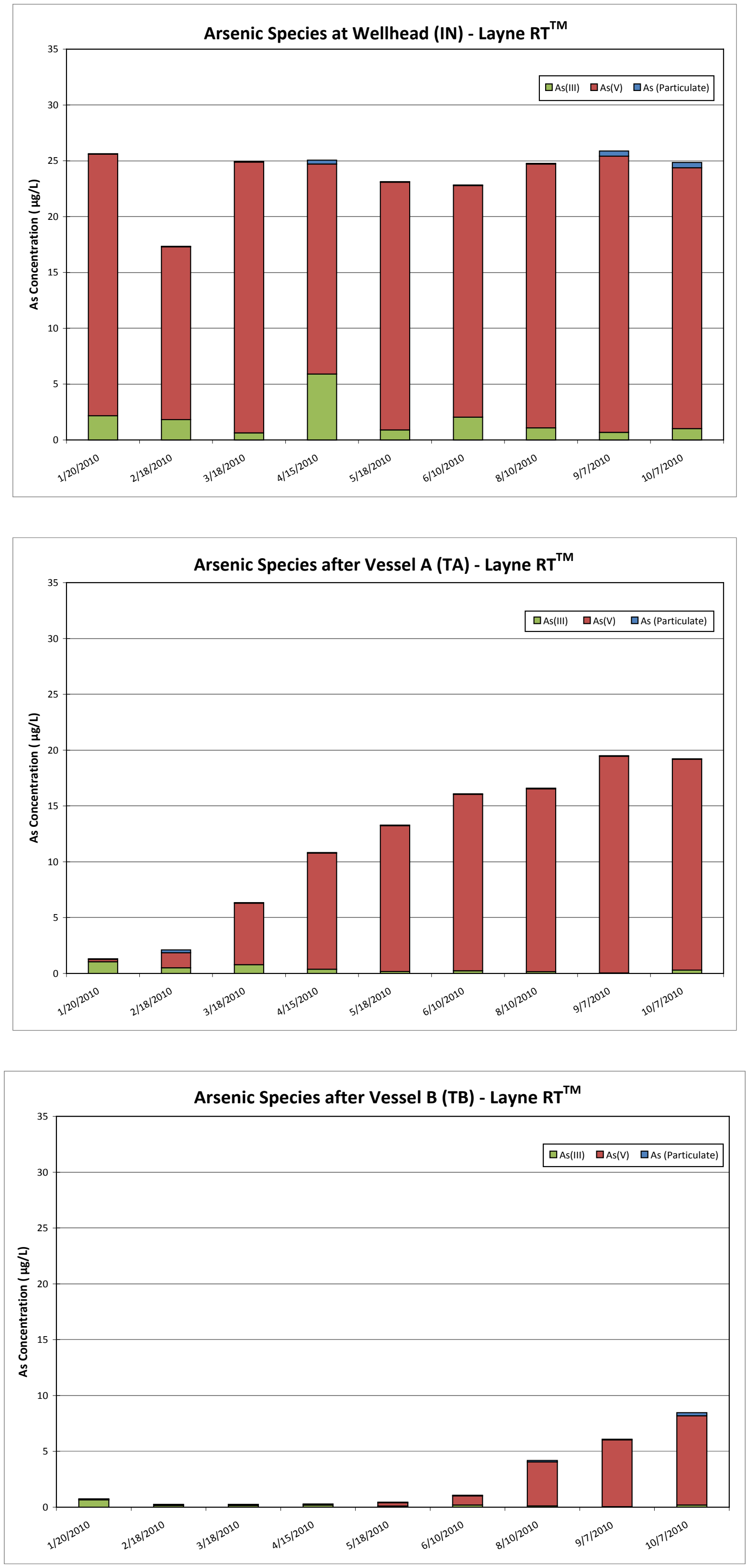


Figure 4-11. Arsenic Species at IN, TA and TB Sampling Locations with LayneRT™ Media

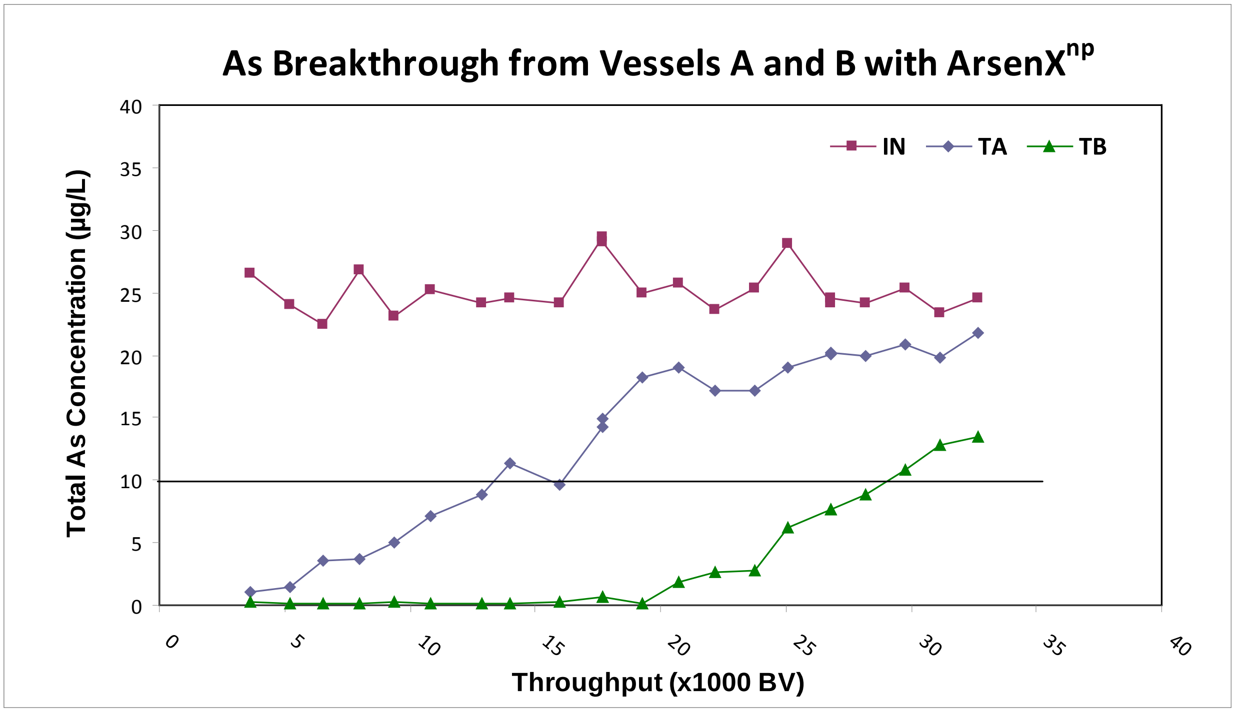


Figure 4-12. Total Arsenic Breakthrough Curves for ArsenX^{np} Media
(1 BV = 2.3 ft^3 = 17.2 gal)

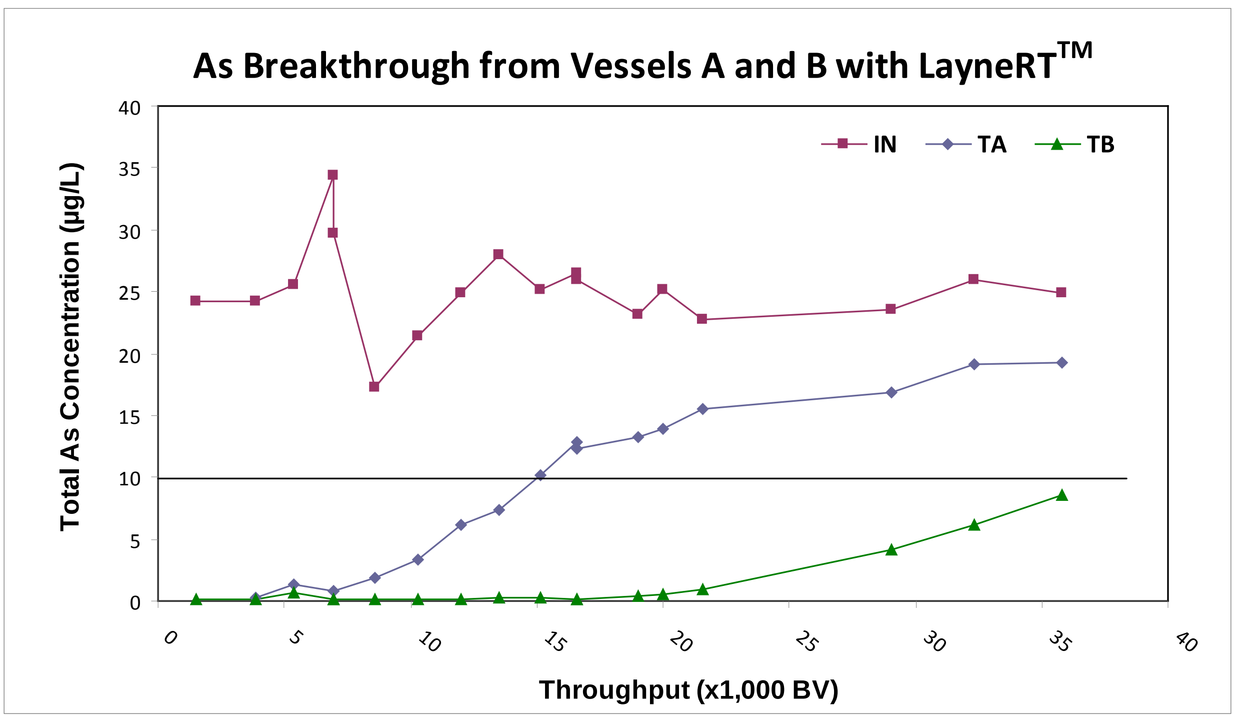


Figure 4-13. Total Arsenic Breakthrough Curves for LayneRT™ Media
(1 BV = 2.3 ft^3 = 17.2 gal)

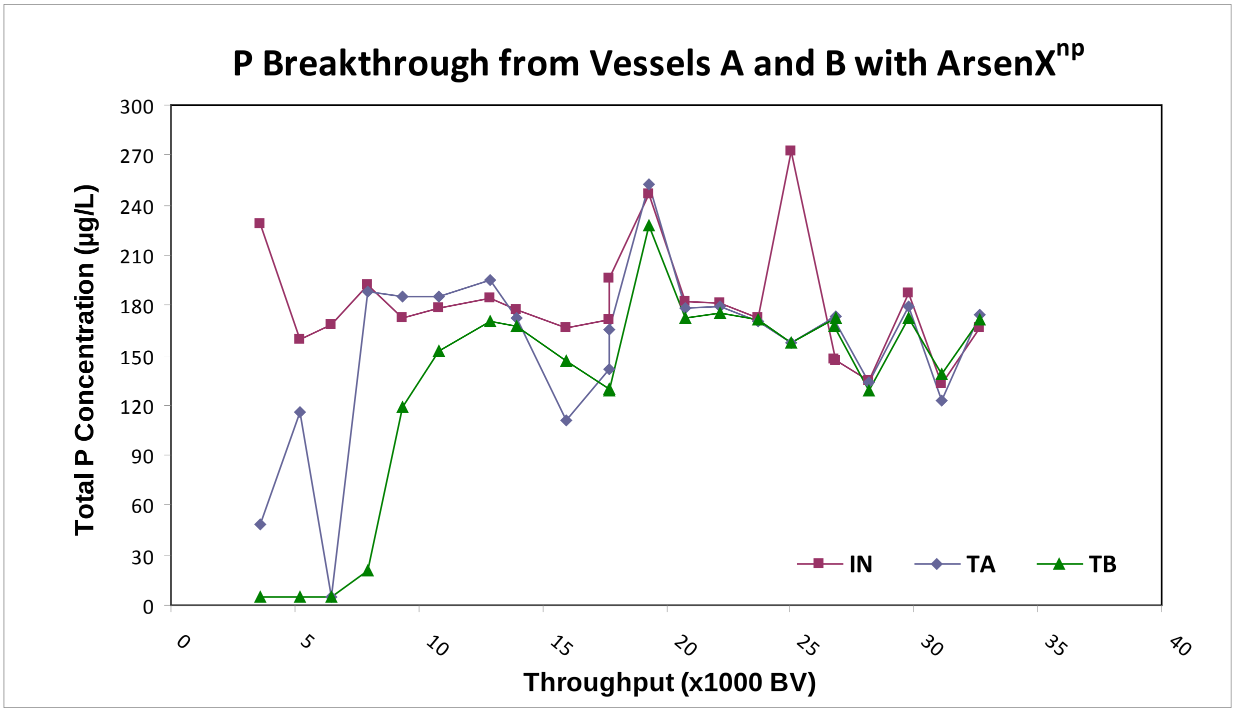


Figure 4-14. Phosphorus Breakthrough Curves for ArsenX^np Media
(1 BV = 2.3 ft^3 = 17.2 gal)

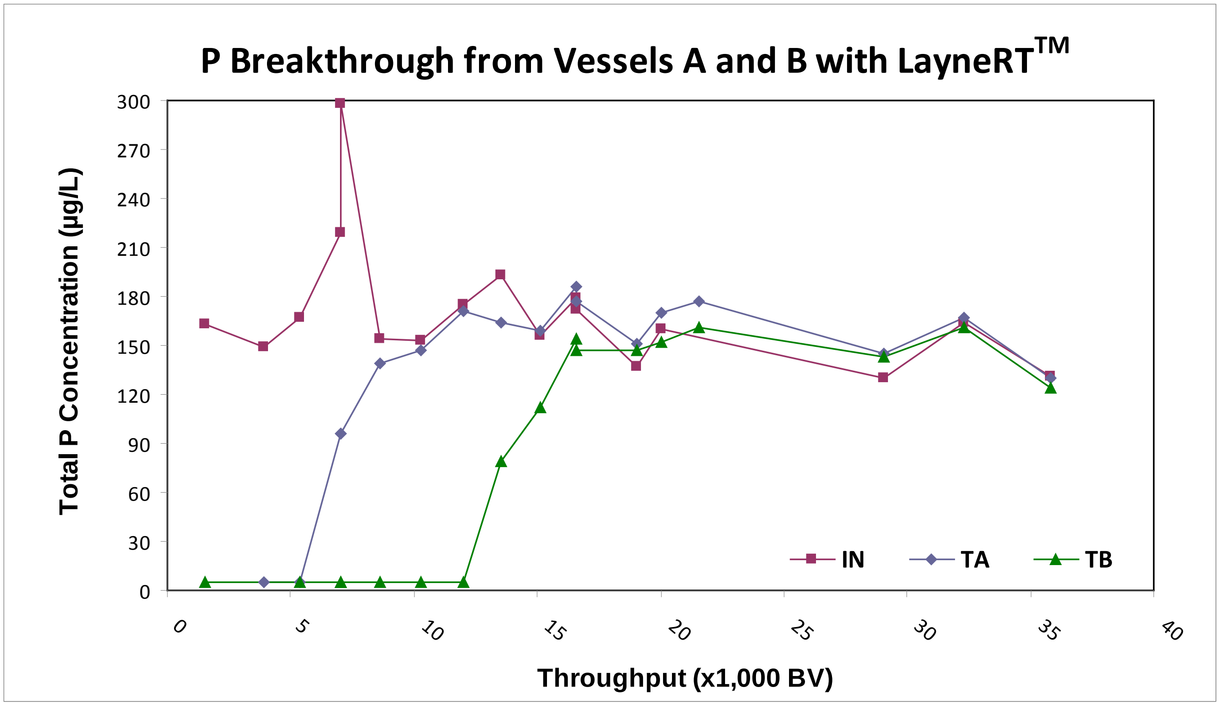


Figure 4-15. Phosphorus Breakthrough Curves for LayneRT™ Media
(1 BV = 2.3 ft^3 = 17.2 gal)

After Vessels A and B, iron and manganese (as particulates) were mostly removed to the MDL of 25 µg/L for iron and below 2.4 and 0.8 µg/L (on average), respectively, for manganese.

4.5.2 Distribution System Water Sampling. Prior to installation/operation of the treatment system, four first-draw baseline samples were collected from a kitchen sink on November 17, December 4, December 11, and December 17, 2008. After system startup, distribution system water sampling continued monthly at the kitchen sink on 10 and six occasions with ArsenX^{np} and LayneRT™, respectively, in the system. Table 4-8 presents results of the distribution system water sampling. Because the November 17, 2009, baseline results from the nurses sink and staff dining room sink were similar to those from the kitchen sink, they are not included in the table.

Table 4-8. Distribution System Water Sampling Results (Kitchen Sink)

Sampling Event	Sampling Date	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu
		hr	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BL1	11/17/08	11.0	7.9	45.8	25.2	<25	4.7	<0.1	24.0
BL2	12/04/08	16.0	8.0	48.9	25.5	<25	3.2	<0.1	46.1
BL3	12/11/08	10.1	8.0	48.9	23.6	31	5.3	<0.1	26.8
BL4	12/17/08	11.5	8.1	50.1	23.1	<25	3.0	<0.1	53.2
1	03/26/09	NA	7.8	48.5	1.4	<25	0.2	<0.1	25.8
2	04/23/09	NA	8.0	48.2	1.5	<25	0.3	<0.1	35.7
3	05/20/09	NA	8.0	47.6	5.5	<25	0.4	0.1	34.4
4	06/17/09	NA	7.9	51.3	1.3	<25	0.2	<0.1	35.1
5	07/15/09	NA	7.8	49.7	1.5	<25	0.2	<0.1	43.6
6	08/12/09	NA	8.0	48.0	2.8	<25	0.2	0.1	50.7
7	09/09/09	NA	7.8	49.9	2.1	<25	0.1	<0.1	41.8
8	10/08/09	NA	8.0	50.9	6.2	<25	0.4	0.2	50.5
9	11/05/09	NA	7.8	60.1	10.4	<25	1.2	<0.1	31.5
10	12/02/09	NA	7.8	55.6	9.1	<25	0.4	0.2	59.2
11	01/07/10	NA	7.9	49.3	1.4	<25	0.2	0.1	53.1
12	02/03/10	17.0	6.6	55.7	1.3	<25	0.3	0.1	57.0
13	03/03/10	11.5	7.8	56.5	0.6	<25	3.7	<0.1	28.0
14	04/01/10	10.6	7.9	55.4	1.3	<25	0.2	0.1	36.2
15	04/28/10	NA	7.8	57.3	0.9	<25	0.2	0.1	30.4
16	05/27/10	14.9	7.8	48.6	1.0	<25	0.2	<0.1	36.0

BL = baseline sampling; NA = not available
Lead action level = 15 µg/L; copper action level = 1.3 mg/L
Unit for alkalinity expressed as $CaCO_3$.

The most noticeable change in the distribution system water samples since system startup was a decrease in arsenic concentration when either media was in the system. Baseline arsenic concentrations ranged from 23.1 to 25.5 µg/L and averaged 24.3 µg/L. After system startup, arsenic concentrations were reduced to 1.3 to 10.4 µg/L with ArsenX^{np} in the system during Sutdy Period I and to 0.6 to 1.4 µg/L with LayneRT™ in the system during Study Period II. Arsenic was above the MCL during only one sampling event just before ArsenX^{np} was replaced.

During Study Period I, arsenic concentrations essentially mirrored those in system effluent throughout the ArsenX^{np} adsorption run, but were generally higher than those in system effluent when system effluent concentrations were low in the 0.1 to 2.8 µg/L range. Similarly, higher concentrations in distribution system water also were observed during the first five to six months of system operation in Study Period II when the monthly distribution system water sampling continued. Some solublization, destablization, and/or desorption of arsenic-laden particles/scales in the distribution system might have occurred, contributing to the higher concentrations observed. Similar observations were made by other researchers (Lytle and Sorg, 2005) and at other arsenic demonstration sites (Chen et al., 2011; Chen et al., 2010a; Chen et al., 2010b; Lipps et al. 2010; Wang et al., 2010a; Wang et al., 2010b; Wang et al., 2010c; Chen et al., 2009a; Chen et al., 2009b; Condit et al., 2009; McCall et al., 2008; Condit and Chen, 2006).

Except for one instance where 31 µg/L of iron was measured during baseline sampling, iron concentrations were below the MDL of 25 µg/L both before and after system startup regardless which media was used in the system. Baseline manganese concentrations were low, ranging from 3.0 to 5.3 µg/L and averging 4.1 µg/L. After system startup, its concentrations remained low from 0.1 to 1.2 µg/L in Study Period I and from 0.2 to 3.7 µg/L in Study Period II. These concentrations were very close to the iron and manganese concentrations in system effluent during both study periods.

Lead concentrations of all water samples collected before and after system startup were equal to or below the reporting limit of 0.1 µg/L in all but two cases, where 0.2 µg/L was measured. Copper concentrations ranged from 24.0 to 53.2 µg/L and averaged 37.5 µg/L before system startup. These concentrations were comparable to those after system startup, ranging from 25.8 to 59.2 µg/L and averaging 40.6 µg/L. No sample exceeded the 1,300 µg/L action level both before and after system startup. The arsenic treatment system did not appear to have an effect on the lead or copper concentration in the distribution system.

4.6 System Cost

The cost of the treatment system was evaluated based on the capital cost per gpm (or gpd) of the design capacity and the O&M cost per 1,000 gal of water treated. This required tracking of the capital cost for the equipment, site engineering, and installation and the O&M cost for media replacement and disposal, chemical supply, electricity consumption, and labor.

4.6.1 Capital Cost. The capital investment for equipment, site engineering, and installation for the 15-gpm treatment system was $17,255 (Table 4-9). The equipment and site engineering cost was $11,345 (or 66% of the total capital investment), including $10,995 for the treatment system and media and $350 for freight. The site engineering cost was not broken out from the equipment cost.

The installation cost included subcontractor travel to the site and subcontractor labor to unload and install the system, perform piping tie-ins and electrical work, and load the media. The installation cost was $5,910, or 34% of the total capital investment.

The capital cost of $17,255 was normalized to the system's rated capacity of 15 gpm (or 21,600 gpd), which results in $1,150.33/gpm (or $0.80/gpd) of design capacity. The capital cost also was converted to an annualized cost of $1,629/year using a capital recovery factor (CRF) of 0.09439 based on a 7% interest rate and a 20-yr return period. Assuming that the system operated 24 hr/day, 7 day/wk at the design flowrate of 15 gpm to produce 7,884,000 gal/year, the unit capital cost would be $0.21/1,000 gal. During the 20 month-long demonstration project, the system produced approximately 1,151,500 gal of water based on Vessel A totalizer for both study periods (see Table 4-5), equivalent to 706,000 gal per year. At this reduced rate of usage, the unit capital cost increased to $2.31/1,000 gal.

Table 4-9. Capital Investment Cost for Seely-Brown Village Treatment System

Description	Quantity	Cost	% of Capital Investment Cost
Equipment and Site Engineering Cost			
ArsenX^{np} Media	4.6 ft^3	$6,300	–
Pressure Vessels	2	$1,600	–
Process Valves and Piping	1	$2,095	–
Instrumentation and Controls	1	$1,000	–
	Subtotal	$10,995	
Shipping		$350	
Equipment Total	–	**$11,345**	**66%**
Installation Cost			
Subcontractor Material	–	$2,000	–
Subcontractor Labor	–	$3,800	–
Subcontractor Travel		$110	
Installation Total	–	**$5,910**	**34%**
Total Capital Investment	–	**$17,255**	**100%**

4.6.2 Operation and Maintenance Cost. The O&M cost includes media replacement and disposal, pre-filter replacement, electricity, and labor, as summarized in Table 4-10. The media was replaced during the performance evaluation study and its cost represents the majority of the O&M cost. Although both the lead and lag vessels were replaced, only the lead vessel would be replaced in the future. Therefore, the O&M cost analysis was performed based on the cost of replacing only the lead vessel. The cost to replace the lead vessel was $2,740, including $1,960 for a replacement vessel and 2.3 ft^3 of LayneRT™ and $780 for miscellaneous items and labor (see Table 4-10). (Note that during actual media changeout at Seely-Brown Village, the vendor replaced the lag vessel at no cost as a promotion for its new LayneRT™ media.) The $2,740 cost was used to estimate the media replacement cost per 1,000 gal of water treated as a function of the projected media run length to the 10-µg/L arsenic breakthrough (Figure 4-16).

The cost for replacing pre-filters was $456, based on replacement of 24 filters/year at a unit cost of $19/filter. The unit filter replacement cost was estimated to be $0.65/1,000 gal of water treated. Comparison of electrical bills provided by the school before and after system startup did not indicate any noticeable increase in power consumption by the treatment system. Therefore, electrical cost associated with operation of the treatment system was negligible. Under normal operating conditions, routine labor activities to operate and maintain the system consumed approximately 20 min/day or 1.6 hr/week. Assuming an hourly rate of $20/hr, the estimated labor cost would be $2.36/1,000 gal of water treated.

Table 4-10. Seely-Brown Village Treatment System Operation and Maintenance Cost

Cost Category	Value	Assumptions
Volume Processed (gal)	1,151,500	From 02/04/09, through 09/24/10, equivalent to 706,000/year
Media Replacement and Disposal		
Replacement Media Vessel	$1,960	For 2.3 ft^3 of LayneRT™ and a replacement vessel (old vessel disposed of)
Vessel Sanitization	$2,00	$100/vessel
Jumbo Cart Filter and Sanitization	$65	
Labor	$360	$90/hr for 4 hr
Tax	$155	
Subtotal ($)	$2,740	
LayneRT Media Replacement and Disposal Cost/1,000 gal	See Figure 4-16	
Pre-filter Replacement Cost		
Annual Filter Replacement	$456	Replacing 24 filters per year at $19/filter
Filter Replacement Cost/1,000 gal	$0.65	
Electricity		
Electricity Cost ($/1,000 gal)	0	Electrical cost assumed negligible
Labor		
Average Weekly Labor (hr)	1.6	20 min/day for 5 days
Annual Labor Cost ($)	1,664	At $20/hr for 52 weeks
Labor Cost/1,000 gal ($)	2.36	
Total O&M Cost/1,000 gal	See Figure 4-16	Total O&M cost = media replacement and disposal cost + $0.65 + $2.36

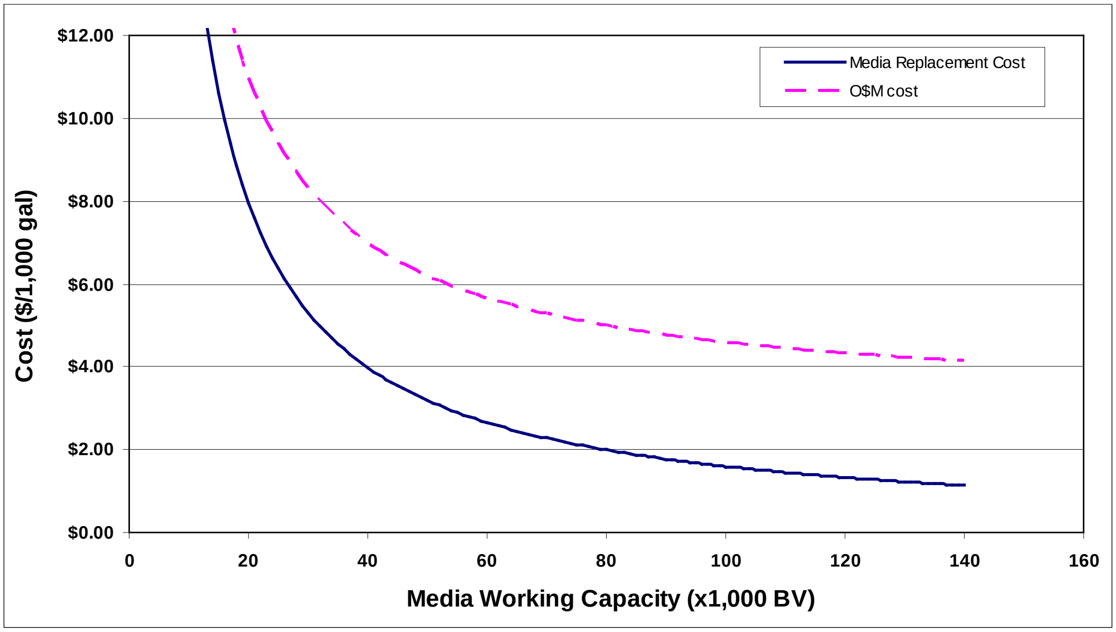


Figure 4-16. Media Replacement and Total O&M Cost Curves
(1 BV = 2.3 ft^3 = 17.2 gal)

5.0 REFERENCES

Battelle. 2008. *System Performance Evaluation Study Plan. U.S. EPA Demonstration of Arsenic Removal Technology Round 2a at Clinton Christian School in Goshen, Indiana.* Prepared under Contract No. EP-C-05-057, Task Order No. 0019, for U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Battelle. 2007. *Quality Assurance Project Plan for Evaluation of Arsenic Removal Technology (QAPP ID 355-Q-6-0).* Prepared under Contract No.EP-C-05-057. Task Order No. 0019, for U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Chen, A.S.C., J.P. Lipps, R.J. Stowe, B.J. Yates, Vivek Lal, and L. Wang. 2011. *Arsenic Removal from Drinking Water by Adsorptive Media. U.S. EPA Demonstration Project at LEADS Head Start Building in Buckeye Lake, OH. Final Performance Evaluation Report.* EPA/600/R-11/002. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Chen, A.S.C., W.E. Condit, B.J. Yates, and L. Wang. 2010a. *Arsenic Removal from Drinking Water by Iron Removal. U.S. EPA Demonstration Project at Sabin, MN. Final Performance Evaluation Report.* EPA/600/R-10/033. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Chen, A.S.C., G.M. Lewis, L. Wang, and A. Wang. 2010b. *Arsenic Removal from Drinking Water by Coagulation/Filtration. U.S. EPA Demonstration Project at Town of Felton, DE. Final Performance Evaluation Report.* EPA/600/R-10/039. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Chen, A.S.C., J.P. Lipps, S.E. McCall, and L. Wang. 2009a. *Arsenic Removal from Drinking Water by Adsorptive Media. U.S. EPA Demonstration Project at Richmond Elementary School in Susanville, CA. Final Performance Evaluation Report.* EPA/600/R-09/067. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Chen, A.S.C., L. Wang, and W.E. Condit. 2009b. *Arsenic Removal from Drinking Water by Iron Removal. U.S. EPA Demonstration Project at Viintage on the Ponds in Delavan, WI. Final Performance Evaluation Report.* EPA/600/R-09/066. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Chen, A.S.C., L. Wang, J.L. Oxenham, and W.E. Condit. 2004. *Capital Costs of Arsenic Removal Technologies: U.S. EPA Arsenic Removal Technology Demonstration Program Round 1.* EPA/600/R-04/201. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Condit, W.E., A.S.C. Chen, L. Wang, and A. Wang. 2009. *Arsenic Removal from Drinking Water by Iron Removal and Adsorptive Media. U.S. EPA Demonstration Project at Stewart, MN. Final Performance Evaluation Report.* EPA/600/R-09/144. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Condit, W.E. and A.S.C. Chen. 2006. *Arsenic Removal from Drinking Water by Iron Removal. U.S. EPA Demonstration Project at Climax, MN. Final Performance Evaluation Report.* EPA/600/R-

06/152. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Cumming, L.J., A.S.C. Chen, and L. Wang. 2009. *Arsenic and Antimony Removal from Drinking Water by Adsorptive Media. U.S. EPA Demonstration Project at South Truckee Deadows General Improvement District (STMGID), NV. Final Performance Evaluation Report.* EPA/600/R-09/016. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Edwards, M., S. Patel, L. McNeill, H. Chen, M. Frey, A.D. Eaton, R.C. Antweiler, and H.E. Taylor. 1998. "Considerations in As Analysis and Speciation." *J. AWWA, 90(3)*: 103-113.

EPA. 2001. National Primary Drinking Water Regulations: Arsenic and Clarifications to Compliance and New Source Contaminants Monitoring. *Federal Register*, 40 CFR Parts 9, 141, and 142.

EPA. 2002. *Lead and Copper Monitoring and Reporting Guidance for Public Water Systems*. EPA/816/R-02/009. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

EPA. 2003. Minor Clarification of the National Primary Drinking Water Regulation for Arsenic. *Federal Register*, 40 CFR Part 141.

Lipps, J.P., A.S.C. Chen, L. Wang, A. Wang, and S.E. McCall. 2010. *Arsenic Removal from Drinking Water by Adsorptive Media. U.S. EPA Demonstration Project at Spring Brook Mobile Home Park in Wales, ME. Final Performance Evaluation Report.* EPA/600/R-10/012. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

LJB Inc. 2007. Water Treatment System Improvements. Clinton Christian School PWS ID# 2200025.

Lytle, D.A. and T.J. Sorg. 2005. "Distribution System Issues." Presented at the Workshop on Arsenic Removal from Drinking Water – August 16 to 18, Cincinnati, OH.

McCall, S.E., A.S.C. Chen, and L. Wang. 2008. *Arsenic Removal from Drinking Water by Adsorptive Media. U.S. EPA Demonstration Project at Bow, NH. Final Performance Evaluation Report.* EPA/600/R-08/006. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Wang A, A.S.C. Chen, and L, Wang. 2010a. *Arsenic Removal from Drinking Water by Adsorptive Media. U.S. EPA Demonstration Project at Lead, SD. Final Performance Evaluation Report.* EPA/600/R-10/179. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH

Wang, L., A.S.C. Chen, and G.M. Lewis. 2010b. *Arsenic and Uranium Removal from Drinking Water by Adsorptive Media. U.S. EPA Demonstration Project at Upper Bodfish in Lake Isabella, CA. Final Performance Evaluation Report.* EPA/600/R-10/165. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Wang, L., A.S.C. Chen, and A. Wang. 2010c. *Arsenic Removal from Drinking Water by Adsorptive Media. U.S. EPA Demonstration Project at Oak Manor Municipal Utility District at Alvin, TX. Final Performance Evaluation Report.* EPA/600/R-10/045. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Wang, L., W.E. Condit, and A.S.C. Chen. 2004. *Technology Selection and System Design: U.S. EPA Arsenic Removal Technology Demonstration Program Round 1.* EPA/600/R-05/001. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Wang, L., A.S.C. Chen, and K.A. Fields . 2000. *Arsenic removal from Drinking Water by Ion Exchange and Activated Alumina Plants.* EPA/600/R-00/088. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

APPENDIX A

OPERATIONAL DATA

Table A-1. EPA Arsenic Demonstration Project at Pomfret, CT- Daily System Operation Log Sheet

			Well No. 1				Well No. 2				Vessels A & B			Throughput				System Pressure			
Week No.	Date	Time	Hour meter	Pump 1 Totalizer	Calculated Inlet Flowrate	Well 1 Pressure	Hour meter	Pump 2 Totalizer	Calculated Inlet Flowrate	Well 2 Pressure	Instant Flow rate	Totalizer 1	Totalizer 2	Volume Treated Vessel A	Cum. Bed Volumes Treated Vessel A	Volume Treated Vessel B	Cum. Bed Volumes Treated Vessel B	Pressure Before pre-filter	Inlet Pressure Vessel A	Outlet Pressure Vessel A	Outlet Pressure Vessel B
			hr	gal	gpm	psi	hr	gal	gpm	psi	gpm	gal	gal	gal	BV	gal	BV	psi	psi	psi	psi
1	2/4/09	16:00	2,109.6	413,100	NA	30	1,015.2	430,200	NA	31	9.61	6,882.78	6,743.56	NA	NA	NA	NA	28	27	20	12
	2/5/09	15:10	2,112.9	414,200	5.6	18	1,018.6	431,100	4.4	17	6.64	762.58	617.86	NA	NA	NA	NA	15	14	10	6
	2/6/09	14:45	2,112.9	415,100	NA	31	1,022.4	431,800	3.1	30	9.78	1,022.76	1,008.64	260	15	391	23	30	28	30	13
2	2/10/09	8:20	2,122.5	418,300	5.6	32	1,032.0	434,200	4.2	30	9.76	15,746	15,602.40	14,724	871	14,594	871	29	28	20	13
	2/11/09	15:20	2,127.4	419,900	5.4	32	1,036.9	435,500	4.4	31	9.78	18,535	18,390.70	2,789	1,033	2,788	1,033	30	28	20	13
	2/12/09	14:42	2,129.8	420,000	0.7	31	1,039.3	436,100	4.2	32	9.87	19,183	19,738.20	648	1,071	1,348	1,112	30	28	20	13
	2/13/09	14:50	2,132.7	421,700	9.8	31	1,042.2	436,900	4.6	32	9.81	21,588	21,444.10	2,405	1,211	1,706	1,211	30	28	20	13
3	2/16/09	14:15	2,141.4	424,500	5.4	31	1,050.9	439,100	4.2	32	9.81	26,533	26,832.90	4,946	1,498	5,389	1,524	30	28	20	13
	2/17/09	14:55	2,145.2	425,800	5.7	32	1,054.7	440,100	4.4	33	9.83	28,688	28,543.30	2,154	1,624	1,710	1,624	30	28	20	13
	2/18/09	15:15	2,147.8	426,700	5.8	31	1,057.3	440,700	3.8	32	9.87	30,191	30,046.30	1,504	1,711	1,503	1,711	30	28	20	13
	2/19/09	15:05	2,150.2	427,500	5.6	31	1,059.7	441,400	4.9	32	9.81	31,590	31,444.80	1,399	1,792	1,399	1,792	30	28	20	13
	2/20/09	7:40	2,151.0	427,700	4.2	31	1,060.5	441,600	4.2	32	9.93	32,068	31,923.10	478	1,820	478	1,820	30	28	20	13
4	2/24/09	15:50	2,164.6	432,200	5.5	33	1,074.1	445,100	4.3	35	9.83	39,792	39,647.00	7,725	2,269	7,724	2,269	31	29	20	13
	2/25/09	15:15	2,166.7	432,900	5.6	33	1,076.2	445,600	4.0	35	9.91	40,989	40,837.50	1,196	2,339	1,191	2,338	32	30	21	14
	2/26/09	14:35	2,169.7	433,900	5.6	32	1,079.2	446,400	4.4	33	9.40	42,719	42,574.10	1,730	2,439	1,737	2,439	30	28	20	12
	2/27/09	16:45	2,174.9	434,800	2.9	31	1,081.3	446,600	1.6	32	9.83	44,175	44,033.40	1,456	2,524	1,459	2,524	30	28	20	13
5	3/2/09	15:10	2,182.3	438,100	7.4	35	1,091.8	449,600	4.8	35	9.76	49,897	49,752.30	5,722	2,857	5,719	2,857	33	30	20	13
	3/3/09	16:05	2,184.9	438,900	5.1	35	1,094.3	450,200	4.0	36	9.78	51,338	51,193.30	1,441	2,940	1,441	2,940	33	30	20	13
	3/4/09	14:35	2,187.1	439,600	5.3	35	1,098.4	450,800	2.4	36	9.76	52,544	52,395.40	1,206	3,011	1,202	3,010	33	29	20	13
	3/5/09	14:20	2,190.1	440,600	5.6	35	1,099.5	451,600	12.1	36	9.70	54,299	54,154.10	1,755	3,113	1,759	3,113	34	30	20	13
	3/6/09	14:55	2,192.8	441,900	8.0	35	1,102.7	452,400	4.2	36	9.74	55,833	55,684.60	1,535	3,202	1,531	3,202	33	30	20	13
6	3/9/09	15:30	2,203.3	444,900	4.8	35	1,112.7	454,900	4.2	36	9.72	61,748	61,603.30	5,915	3,546	5,919	3,546	34	30	20	12
	3/10/09	15:10	2,205.7	445,700	5.6	35	1,115.1	455,500	4.2	36	9.68	63,106	62,961	1,358	3,625	1,358	3,625	34	29	20	12
	3/11/09	9:20	2,207.1	446,200	6.0	35	1,116.5	455,900	4.8	35	9.51	63,905	63,760	799	3,671	799	3,671	34	29	20	12
	3/13/09	14:05	2,217.6	449,500	5.2	37	1,126.9	458,500	4.2	39	9.59	69,678	69,353	5,774	4,007	5,593	3,996	34	29	20	12
7	3/16/09	9:45	2,224.5	451,900	5.8	36	1,133.8	460,250	4.2	40	9.59	73,587	73,350	3,908	4,234	3,997	4,229	38	29	21	13
	3/17/09	9:20	2,228.0	453,000	5.2	38	1,137.3	461,130	4.2	39	9.61	75,541	75,351	1,954	4,348	2,001	4,345	37	29	20	12
	3/18/09	9:30	2,231.5	454,100	5.2	39	1,140.8	462,000	4.1	40	9.57	77,495	77,350	1,954	4,461	1,999	4,461	37	29	20	12
	3/19/09	8:20	2,234.8	455,600	7.6	39	1,144.2	462,800	3.9	40	9.54	79,330	79,181	1,834	4,568	1,831	4,568	37	29	20	11
	3/20/09	7:50	2,238.2	456,200	2.9	39	1,147.5	463,700	4.5	40	9.44	81,164	81,016	1,835	4,675	1,835	4,674	37	29	20	11
8	3/23/09	12:10	2,246.2	458,750	5.3	39	1,155.5	465,700	4.2	40	9.47	85,608	85,461	4,444	4,933	4,445	4,933	38	32	20	11
	3/24/09	13:25	2,250.3	460,030	5.2	39	1,159.6	466,600	3.7	40	9.47	87,829	87,683	2,221	5,062	2,222	5,062	38	32	20	11
	3/25/09	16:20	2,254.4	461,300	5.2	39	1,163.7	467,700	4.5	40	9.49	90,050	89,906	2,222	5,191	2,223	5,191	39	28	20	11
	3/26/09	13:50	2,257.2	462,200	5.4	39	1,166.4	468,400	4.3	40	9.46	91,585	91,440	1,535	5,280	1,535	5,280	39	28	20	11
	3/27/09	11:28	2,260.1	463,100	5.2	40	1,169.3	469,100	4.0	41	9.44	93,120	92,975	1,535	5,370	1,535	5,370	39	28	19	11
9	3/30/09	14:25	2,269.1	465,900	5.2	39	1,178.3	471,300	4.1	40	9.44	98,020	97,874	4,900	5,655	4,899	5,654	39	28	20	11
	3/31/09	15:00	2,273.5	467,300	5.3	39	1,182.8	472,400	4.1	40	9.44	100,470	100,324	2,450	5,797	2,450	5,797	40	25	18	10
	4/1/09	16:10	2,276.6	468,300	5.4	42	1,185.9	473,100	3.8	44	9.36	102,116	101,971	1,646	5,893	1,647	5,893	40	28	19	11
	4/2/09	14:50	2,279.1	469,100	5.3	41	1,188.4	473,700	4.0	42	9.42	103,486	103,341	1,370	5,972	1,370	5,972	40	28	20	11
	4/3/09	15:10	2,280.9	470,200	10.2	41	1,190.9	474,300	4.0	42	9.42	104,857	104,715	1,371	6,052	1,374	6,052	40	28	20	11

Table A-1. EPA Arsenic Demonstration Project at Pomfret, CT - Daily System Operation Log Sheet (Continued)

			Well No. 1				Well No. 2				Vessels A & B			Throughput				System Pressure			
Week No.	Date	Time	Hour meter	Pump 1 Totalizer	Calculated Inlet Flowrate	Well 1 Pressure	Hour meter	Pump 2 Totalizer	Calculated Inlet Flowrate	Well 2 Pressure	Instant Flow rate	Totalizer 1	Totalizer 2	Volume Treated Vessel A	Cum. Bed Volumes Treated Vessel A	Volume Treated Vessel B	Cum. Bed Volumes Treated Vessel B	Pressure Before pre-filter	Inlet Pressure Vessel A	Outlet Pressure Vessel A	Outlet Pressure Vessel B
			hr	gal	gpm	psi	hr	gal	gpm	psi	gpm	gal	gal	gal	BV	gal	BV	psi	psi	psi	psi
	4/6/09	8:30	2,291.2	472,800	4.2	42	1,200.5	476,700	4.2	43	9.29	109,965	109,816	5,108	6,349	5,101	6,349	42	28	19	11
	4/7/09	8:45	2,293.7	473,600	5.3	42	1,203.0	477,300	4.0	43	9.29	111,312	111,166	1,347	6,427	1,350	6,427	42	28	19	11
10	4/8/09	8:20	2,296.3	474,400	5.1	42	1,205.6	477,900	3.8	43	9.29	112,661	112,516	1,349	6,506	1,350	6,506	42	28	19	11
	4/9/09	8:30	2,299.1	475,300	5.4	43	1,209.8	478,500	2.4	43	9.29	114,138	113,993	1,477	6,592	1,477	6,592	42	28	19	11
	4/10/09	8:00	2,301.9	476,100	4.8	45	1,211.2	479,200	8.3	45	9.29	115,615	115,470	1,477	6,677	1,477	6,677	43	28	18	10
	4/13/09	14:50	2,312.8	479,400	5.0	45	1,222.4	481,900	4.0	44	9.2	121,341	121,199	5,726	7,010	5,729	7,011	44	27	19	10
11	4/14/09	15:20	2,316.5	480,500	5.0	45	1,225.8	482,700	3.9	45	9.19	123,249	123,104	1,908	7,121	1,905	7,121	44	27	19	10
	4/16/09	9:00	2,320.4	481,700	5.1	35	1,229.6	483,600	3.9	35	9.81	126,181	126,035	2,932	7,292	2,931	7,292	30	30	20	13
	4/17/09	16:05	2,325.3	483,300	5.4	35	1,234.6	484,900	4.3	35	9.91	128,202	128,057	2,021	7,409	2,022	7,409	32	30	21	13
	4/20/09	9:15	2,333.1	485,900	5.6	35	1,242.4	486,900	4.3	35	9.89	132,707	132,561	4,505	7,671	4,504	7,671	33	30	20	13
	4/21/09	9:22	2,336.4	486,800	4.5	35	1,245.5	487,700	4.3	35	9.89	134,404	134,357	1,697	7,770	1,796	7,776	33	30	20	13
12	4/22/09	9:43	2,339.7	487,900	5.6	35	1,248.7	488,600	4.7	35	9.89	136,103	136,155	1,699	7,869	1,798	7,880	33	30	21	13
	4/23/09	8:55	2,342.7	489,000	6.1	34	1,251.6	489,300	4.0	35	9.89	137,780	137,948	1,677	7,966	1,793	7,984	32	30	21	13
	4/24/09	10:55	2,346.8	490,400	5.7	34	1,256.0	490,400	4.2	35	9.85	140,499	140,499	2,719	8,124	2,551	8,133	32	30	20	13
	4/27/09	8:00	2,353.4	492,600	5.6	34	1,262.6	492,100	4.3	35	9.87	144,271	144,125	3,772	8,344	3,626	8,343	32	30	20	13
	4/28/09	8:00	2,356.7	493,700	5.6	34	1,265.9	493,000	4.5	35	9.87	146,157	146,011	1,886	8,453	1,886	8,453	32	30	20	13
13	4/29/09	10:15	2,360.4	495,000	5.9	34	1,269.7	493,900	3.9	35	9.87	148,345	148,195	2,188	8,580	2,184	8,580	32	30	20	13
	4/30/09	9:50	2,364.3	496,300	5.6	34	1,273.5	494,800	3.9	35	9.85	150,531	150,385	2,186	8,707	2,190	8,707	33	30	21	13
	5/1/09	11:00	2,368.2	497,500	5.1	34	1,277.3	495,900	4.8	35	9.85	152,717	152,572	2,186	8,835	2,187	8,835	33	30	21	13
	5/4/09	15:50	2,376.3	500,200	5.6	35	1,285.2	498,000	4.4	35	9.89	157,316	157,366	4,599	9,102	4,794	9,113	33	30	21	13
	5/5/09	17:00	2,380.4	501,600	5.7	35	1,289.5	499,100	4.3	35	9.89	159,615	159,763	2,299	9,236	2,397	9,253	33	30	21	13
14	5/6/09	10:30	2,383.4	502,600	5.6	35	1,292.5	499,800	3.9	35	9.78	161,441	161,296	1,826	9,342	1,533	9,342	33	30	20	13
	5/7/09	12:55	2,387.2	503,800	5.3	35	1,296.3	500,900	4.8	35	9.77	163,637	163,493	2,196	9,469	2,197	9,469	33	29	20	12
	5/8/09	2:15	2,391.1	505,100	5.6	35	1,301.1	501,800	3.1	35	9.69	165,834	165,688	2,197	9,597	2,195	9,597	33	29	20	12
	5/11/09	10:45	2,398.8	505,600	1.1	35	1,307.9	503,800	4.9	35	9.42	170,225	170,079	4,391	9,852	4,391	9,852	33	29	20	11
	5/12/09	14:30	2,404.0	509,300	11.9	37	1,313.1	505,100	4.2	38	9.74	173,135	172,989	2,910	10,022	2,910	10,022	35	30	20	13
15	5/13/09	10:00	2,406.1	510,000	5.6	35	1,315.2	505,600	4.0	37	9.42	174,352	174,206	1,217	10,092	1,217	10,092	35	30	20	11
	5/14/09	11:55	2,409.7	510,900	4.2	36	1,318.7	506,400	3.8	37	9.78	176,044	175,875	1,692	10,191	1,669	10,189	35	30	20	13
	5/15/09	10:45	2,412.1	512,000	7.6	38	1,321.3	507,200	5.1	39	9.81	177,736	177,587	1,692	10,289	1,712	10,289	35	30	20	13
	5/18/09	12:10	2,421.7	515,100	5.4	38	1,330.8	509,600	4.2	39	9.78	183,066	182,920	5,330	10,599	5,333	10,599	35	30	20	13
	5/19/09	14:30	2,426.4	516,600	5.3	39	1,335.5	510,800	4.3	40	9.70	185,731	185,586	2,665	10,754	2,666	10,754	36	30	20	13
16	5/20/09	10:00	2,428.9	517,400	5.3	39	1,338.1	511,400	3.8	40	9.44	187,125	186,980	1,394	10,835	1,394	10,835	35	29	19	12
	5/21/09	14:20	2,432.7	518,600	5.3	39	1,341.8	512,300	4.1	40	9.68	189,229	189,083	2,104	10,957	2,103	10,957	37	30	20	12
	5/22/09	9:45	2,435.0	519,400	5.8	39	1,344.0	512,900	4.5	40	9.19	190,497	190,453	1,268	11,031	1,370	11,037	37	29	20	11
	6/1/09	13:45	2,471.7	531,000	5.3	41	1,380.7	521,900	4.1	42	8.91	210,589	210,444	20,092	12,199	19,991	12,199	40	26	18	10
	6/2/09	14:22	2,474.9	531,900	4.7	41	1,383.8	522,700	4.3	42	9.12	212,293	210,443	1,704	12,298	-1	12,199	40	28	18	11
18	6/3/09	11:36	2,478.3	532,800	4.4	42	1,387.0	523,500	4.2	43	9.37	213,997	212,147	1,704	12,397	1,704	12,298	40	29	19	11
	6/4/09	9:35	2,481.1	533,900	6.5	42	1,390.1	524,300	4.3	43	9.42	215,555	215,555	1,558	12,488	3,408	12,496	40	29	20	11
	6/5/09	11:00	2,486.6	535,600	5.2	43	1,395.6	525,600	3.9	45	8.76	218,501	218,501	2,946	12,659	2,946	12,668	42	25	17	10
	6/8/09	8:00	2,494.8	538,200	5.3	45	1,403.8	527,600	4.1	45	8.63	223,070	222,924	4,569	12,925	4,423	12,925	41	25	17	10
	6/9/09	4:10	2,499.0	539,600	5.6	34	1,407.9	528,700	4.5	35	9.87	225,443	225,293	2,373	13,063	2,369	13,063	33	31	21	13
19	6/10/09	3:55	2,503.1	540,900	5.3	35	1,412.0	529,700	4.1	35	9.92	227,808	227,660	2,365	13,200	2,367	13,200	33	31	21	3
	6/11/09	4:00	2,507.3	542,300	5.6	35	1,416.2	530,800	4.4	36	10.0	230,176	230,031	2,368	13,338	2,371	13,338	33	31	21	13
	6/12/09	1:10	2,512.8	543,600	3.9	32	1,420.9	531,700	3.2	34	9.36	231,801	231,656	1,625	13,432	1,625	13,432	30	30	20	12

Table A-1. EPA Arsenic Demonstration Project at Pomfret, CT - Daily System Operation Log Sheet (Continued)

			Well No. 1				Well No. 2				Vessels A & B			Throughput				System Pressure			
Week No.	Date	Time	Hour meter	Pump 1 Totalizer	Calculated Inlet Flowrate	Well 1 Pressure	Hour meter	Pump 2 Totalizer	Calculated Inlet Flowrate	Well 2 Pressure	Instant Flow rate	Totalizer 1	Totalizer 2	Volume Treated Vessel A	Cum. Bed Volumes Treated Vessel A	Volume Treated Vessel B	Cum. Bed Volumes Treated Vessel B	Pressure Before pre-filter	Inlet Pressure Vessel A	Outlet Pressure Vessel A	Outlet Pressure Vessel B
			hr	gal	gpm	psi	hr	gal	gpm	psi	gpm	gal	gal	gal	BV	gal	BV	psi	psi	psi	psi
20	6/15/09	10:12	2,519.5	546,000	6.0	32	1,427.9	533,800	5.0	34	9.41	236,440	236,296	4,639	13,702	4,640	13,702	30	30	21	13
	6/16/09	10:48	2,522.8	547,300	6.6	34	1,431.6	534,600	3.6	35	9.52	238,760	238,615	2,320	13,837	2,319	13,837	32	30	21	13
	6/17/09	8:50	2,526.2	548,600	6.4	34	1,435.1	535,700	5.2	35	9.55	241,079	240,935	2,319	13,972	2,320	13,972	32	30	21	13
	6/18/09	9:10	2,529.1	549,500	5.2	35	1,437.9	536,300	3.6	35	9.82	242,717	242,572	1,638	14,067	1,637	14,067	33	32	21	13
	6/19/09	8:00	2,531.8	550,500	6.2	35	1,440.7	537,100	4.8	36	9.93	244,355	244,210	1,638	14,162	1,638	14,162	34	32	21	13
21	6/22/09	8:25	2,541.1	553,600	5.6	35	1450.1	539,500	4.3	36	9.78	249,695	249,549	5,340	14,473	5,339	14,473	32	30	20	13
	6/26/09	8:10	2,595.1	561,800	2.5	35	1455.5	545,800	19.4	35	9.89	263,823	263,678	14,128	15,294	14,129	15,294	33	31	21	13
22	6/29/09	8:10	2,606.2	565,500	5.6	35	1466.6	548,700	4.4	35	9.83	270,181	270,035	6,358	15,664	6,357	15,664	33	31	21	13
	6/30/09	8:12	2,613.1	567,700	5.3	35	1473.5	550,400	4.1	35	9.85	274,002	273,857	3,821	15,886	3,822	15,886	34	31	21	13
	7/1/09	8:10	2,616.2	568,700	5.4	35	1476.6	551,200	4.3	35	9.61	275,768	275,624	1,766	15,989	1,767	15,989	32	30	20	13
23	7/6/09	10:12	2,641.4	575,100	4.2	35	1487.3	555,800	7.2	35	9.74	286,409	286,264	10,641	16,607	10,640	16,607	32	30	21	13
	7/7/09	10:48	2,649.8	576,700	3.2	35	1490.8	557,000	5.7	36	9.81	289,069	288,924	2,660	16,762	2,660	16,762	34	31	21	13
	7/8/09	8:50	2,658.2	578,200	3.0	36	1494.3	558,100	5.2	38	9.79	291,729	291,584	2,660	16,917	2,660	16,917	33	31	21	13
	7/9/09	9:10	2,666.7	579,800	3.1	36	1497.8	559,200	5.2	38	9.87	294,389	294,244	2,660	17,071	2,660	17,071	35	31	21	13
	7/10/09	8:00	2,672.1	581,500	5.2	36	1503.1	560,600	4.4	38	9.83	297,428	297,282	3,039	17,248	3,038	17,248	35	31	21	13
24	7/13/09	15:45	2,678.9	583,800	5.6	35	1509.9	562,300	4.2	36	9.78	301,238	301,093	3,810	17,470	3,811	17,469	35	30	21	13
	7/14/09	14:50	2,682.3	584,900	5.4	35	1513.3	563,200	4.4	36	9.76	303,148	302,998	1,910	17,581	1,905	17,580	35	30	20	12
	7/15/09	9:00	2,685.6	586,000	5.6	35	1516.7	564,000	3.9	36	9.12	305,048	304,903	1,900	17,691	1,905	17,691	34	28	19	11
	7/16/09	12:35	2,690.3	587,400	5.0	35	1520.9	565,500	6.0	36	9.14	307,717	307,573	2,669	17,846	2,670	17,846	34	29	20	11
	7/17/09	13:45	2,695.1	589,000	5.6	35	1526.2	566,400	2.8	36	9.14	310,387	310,244	2,670	18,001	2,671	18,002	35	29	20	11
25	7/22/09	12:25	2,701.7	593,700	11.9	35	1543.9	570,100	3.5	36	9.91	318,416	318,271	8,029	18,468	8,027	18,468	33	32	21	13
	7/23/09	13:18	2,705.9	595,100	5.6	35	1548.1	571,100	4.0	36	9.93	320,805	320,569	2,389	18,607	2,298	18,602	34	32	21	13
	7/24/09	9:00	2,707.5	595,600	5.2	35	1549.6	571,500	4.4	36	9.98	321,748	321,603	943	18,662	1,034	18,662	34	32	21	13
26	7/27/09	8:00	2,715.7	598,400	5.7	35	1557.8	573,700	4.5	36	9.76	326,503	326,358	4,755	18,938	4,755	18,938	33	31	21	13
	7/28/09	10:15	2,719.4	599,600	5.4	35	1561.9	574,600	3.7	36	9.83	328,650	328,505	2,147	19,063	2,147	19,063	34	32	21	12
	7/29/09	9:15	2,723.2	600,900	5.7	35	1565.4	575,600	4.8	36	9.91	330,797	330,652	2,147	19,188	2,147	19,188	34	32	21	13
	7/30/09	8:50	2,725.9	601,800	5.6	35	1568.1	576,500	5.6	36	9.76	332,333	332,188	1,536	19,277	1,536	19,277	32	30	21	13
	7/31/09	9:00	2,728.5	602,600	5.1	35	1570.6	577,000	3.3	35	9.93	333,844	333,699	1,511	19,365	1,511	19,365	34	32	21	13
27	8/3/09	8:10	2,738.4	605,900	5.6	35	1580.5	579,500	4.2	36	9.59	339,516	339,371	5,672	19,695	5,672	19,695	33	31	21	13
	8/4/09	9:05	2,742.4	607,200	5.4	35	1584.5	580,500	4.2	35	9.38	341,788	341,642	2,272	19,827	2,271	19,827	31	30	20	12
	8/5/09	9:35	2,745.1	608,100	5.6	35	1587.1	581,200	4.5	35	9.38	343,309	343,164	1,521	19,915	1,522	19,915	32	30	21	12
	8/6/09	8:05	2,747.1	608,800	5.8	35	1589.2	581,800	4.8	35	9.87	344,539	344,394	1,230	19,987	1,230	19,987	34	32	21	13
	8/7/09	9:07	2,749.8	609,800	6.2	35	1591.9	582,500	4.3	35	9.98	346,104	345,959	1,565	20,078	1,565	20,078	35	33	21	13
28	8/10/09	2:24	2,763.5	614,300	5.5	35	1605.7	586,000	4.2	35	9.55	353,956	353,811	7,852	20,535	7,852	20,534	34	32	21	13
	8/11/09	12:00	2,767.8	615,700	5.4	36	1608.1	587,100	7.6	38	9.41	355,910	355,764	1,954	20,648	1,953	20,648	35	33	22	13
	8/12/09	13:12	2,771.1	616,800	5.6	36	1613.1	587,900	2.7	38	8.84	357,454	357,309	1,544	20,738	1,545	20,738	35	33	22	14
	8/13/09	12:00	2,774.9	617,900	4.8	38	1616.8	588,700	3.6	38	9.19	359,058	358,913	1,604	20,831	1,604	20,831	35	33	22	14
	8/14/09	7:12	2,777.2	618,800	6.5	38	1619.3	589,500	5.3	38	9.21	360,662	360,517	1,604	20,924	1,604	20,924	35	34	22	14
29	8/17/09	9:35	2,788.3	622,500	5.6	38	1630.4	592,300	4.2	39	9.31	366,604	366,459	5,942	21,270	5,942	21,270	35	33	22	14
	8/18/09	8:46	2,791.3	623,400	5.0	35	1633.4	593,100	4.4	35	8.76	369,188	369,043	2,584	21,420	2,584	21,420	34	30	20	13
	8/19/09	10:10	2,794.2	624,400	5.7	38	1636.4	593,800	3.9	39	9.29	369,784	369,639	596	21,455	596	21,455	35	33	22	14
	8/20/09	9:55	2,798.3	625,700	5.3	35	1640.8	594,900	4.2	35	8.93	NA	NA	NA	NA	NA	NA	34	31	21	13
	8/21/09	10:18	2,802.3	627,000	5.4	35	1644.4	595,900	4.6	35	8.61	374,929	373,929	5,145	21,754	4,290	21,704	34	30	20	13

Table A-1. EPA Arsenic Demonstration Project at Pomfret, CT - Daily System Operation Log Sheet (Continued)

			Well No. 1				Well No. 2				Vessels A & B			Throughput				System Pressure			
Week No.	Date	Time	Hour meter	Pump 1 Totalizer	Calculated Inlet Flowrate	Well 1 Pressure	Hour meter	Pump 2 Totalizer	Calculated Inlet Flowrate	Well 2 Pressure	Instant Flow rate	Totalizer 1	Totalizer 2	Volume Treated Vessel A	Cum. Bed Volumes Treated Vessel A	Volume Treated Vessel B	Cum. Bed Volumes Treated Vessel B	Pressure Before pre-filter	Inlet Pressure Vessel A	Outlet Pressure Vessel A	Outlet Pressure Vessel B
			hr	gal	gpm	psi	hr	gal	gpm	psi	gpm	gal	gal	gal	BV	gal	BV	psi	psi	psi	psi
30	8/25/09	11:10	2,815.4	631,300	5.5	35	1657.5	599,200	4.2	36	9.49	381,140	380,995	6,211	22,115	7,066	22,115	35	33	22	14
	8/26/09	1:15	2,817.6	632,100	6.1	35	1659.7	599,800	4.5	35	9.53	382,354	382,208	1,214	22,186	1,213	22,185	35	33	22	14
	8/27/09	12:40	2,822.9	633,800	5.3	35	1665.1	601,100	4.0	35	9.27	385,215	385,070	2,861	22,352	2,862	22,352	34	32	21	14
	8/28/09	8:05	2,825.6	634,700	5.6	35	1667.7	601,800	4.5	35	9.53	386,742	386,597	1,527	22,441	1,527	22,441	35	33	22	14
31	8/31/09	9:10	2,834.3	637,500	5.4	35	1676.4	604,000	4.2	35	9.02	391,503	391,358	4,761	22,717	4,761	22,717	32	30	20	13
	9/1/09	8:12	2,838.6	639,000	5.8	36	1680.7	605,100	4.3	38	9.49	393,862	393,717	2,359	22,855	2,359	22,855	35	33	21	13
	9/2/09	8:15	2,842.7	640,300	5.3	35	1684.8	606,100	4.1	35	9.51	396,091	395,945	2,229	22,984	2,228	22,984	35	33	21	13
	9/3/09	8:35	2,847.4	641,800	5.3	35	1689.5	607,300	4.3	35	8.42	398,610	398,465	2,519	23,131	2,520	23,131	33	30	20	13
	9/4/09	9:20	2,850.2	642,700	5.4	38	1692.3	608,000	4.2	39	9.34	400,148	400,002	1,538	23,220	1,537	23,220	36	33	21	14
32	9/9/09	9:45	2,867.1	648,100	5.3	42	1709.1	612,200	4.2	43	8.99	409,037	408,891	8,889	23,737	8,889	23,737	41	30	21	13
	9/11/09	9:55	2,874.5	650,400	5.2	45	1716.6	614,000	4.0	45	8.80	412,870	412,675	3,833	23,960	3,784	23,957	42	30	20	12
33	9/14/09	12:25	2,886.1	653,800	4.9	50	1728.2	616,700	3.9	51	8.72	418,428	418,266	5,558	24,283	5,591	24,282	49	30	18	12
	9/15/09	1:45	2,891.9	655,500	4.9	52	1733.9	618,000	3.8	53	8.40	421,207	421,061	2,779	24,444	2,795	24,444	50	28	18	10
	9/16/09	8:45	2,894.9	656,400	5.0	52	1736.8	618,700	4.0	52	7.71	422,615	422,470	1,408	24,526	1,409	24,526	50	25	15	10
	9/17/09	9:10	2,897.8	657,100	4.0	55	1739.8	619,300	3.3	55	8.20	423,905	423,759	1,290	24,601	1,289	24,601	52	25	17	10
34	9/21/09	8:52	2,916.2	662,000	4.4	60	1758.2	623,100	3.4	60	7.63	431,850	431,704	7,945	25,063	7,945	25,063	60	25	25	10
35	10/1/09	14:33	2,950.2	672,700	5.2	41	1792.2	631,400	4.1	42	9.21	449,560	449,414	17,710	26,093	17,710	26,093	40	32	20	13
	10/2/09	13:55	2,954.6	674,100	5.3	42	1796.6	632,500	4.2	42	8.84	451,867	451,721	2,307	26,227	2,307	26,227	40	30	20	13
36	10/5/09	15:36	2,965.4	677,400	5.1	45	1807.3	635,100	4.0	45	8.69	457,316	457,171	5,449	26,544	5,450	26,544	44	30	20	11
	10/6/09	14:04	2,968.8	678,300	4.4	45	1810.7	635,800	3.4	45	8.79	458,905	458,759	1,589	26,636	1,588	26,636	44	30	20	11
	10/7/09	11:25	2,972.2	679,200	4.4	46	1814.1	636,600	3.9	46	8.43	460,494	460,347	1,589	26,729	1,588	26,728	44	30	20	11
	10/8/09	9:15	2,975.1	680,200	5.7	35	1817.1	637,300	3.9	35	9.34	462,083	461,937	1,589	26,821	1,590	26,821	34	32	21	13
38	10/20/09	11:45	3,014.3	692,800	5.4	45	1855.9	647,100	4.2	45	8.72	483,578	483,578	21,495	28,071	21,641	28,079	43	30	20	11
	10/21/09	8:50	3,018.2	694,000	5.1	45	1860.1	648,000	3.6	45	8.78	485,013	484,868	1,435	28,154	1,290	28,154	43	30	20	11
	10/22/09	2:10	3,022.9	695,400	5.0	45	1864.7	649,100	4.0	45	8.81	487,350	487,205	2,337	28,290	2,337	28,290	44	30	20	11
	10/23/09	10:30	3,025.9	696,400	5.6	35	1867.7	649,800	3.9	35	9.23	488,883	488,737	1,533	28,379	1,532	28,379	34	32	20	13
39	10/26/09	9:10	3,035.9	699,600	5.3	35	1877.7	652,300	4.2	35	8.86	494,336	494,191	5,453	28,696	5,454	28,696	34	31	20	13
	10/27/09	8:35	3,039.3	700,700	5.4	35	1881.1	653,200	4.4	35	8.95	496,154	496,009	1,818	28,802	1,818	28,802	34	30	20	13
	10/28/09	8:50	3,042.1	701,600	5.4	35	1883.9	653,900	4.2	35	9.12	497,672	497,514	1,518	28,890	1,505	28,889	34	31	20	13
	10/29/09	9:24	3,045.2	702,600	5.4	35	1886.8	654,700	4.6	35	9.28	499,191	499,020	1,519	28,978	1,506	28,977	34	32	21	13
	10/30/09	8:00	3,047.7	703,500	6.0	35	1889.5	655,300	3.7	35	9.40	500,708	500,523	1,517	29,067	1,503	29,064	35	34	21	13
40	11/2/09	9:12	3,058.4	706,600	4.8	38	1899.3	657,700	4.1	38	8.57	505,896	505,737	5,188	29,368	5,214	29,367	36	31	20	13
	11/3/09	7:10	3,062.2	708,100	6.6	40	1904.1	658,900	4.2	40	8.99	508,489	508,343	2,593	29,519	2,606	29,519	38	31	20	13
	11/4/09	8:20	3,068.7	710,200	5.4	42	1910.5	660,500	4.2	42	8.57	511,776	511,776	3,287	29,710	3,433	29,718	40	30	19	11
	11/5/09	10:22	3,070.4	710,800	5.9	44	1912.4	661,000	4.4	44	8.79	512,760	512,760	984	29,767	984	29,776	41	30	20	11
	11/6/09	12:00	3,072.6	711,400	4.5	45	1914.3	661,500	4.4	45	8.97	513,744	513,744	984	29,825	984	29,833	43	31	20	11
41	11/9/09	7:00	3,085.6	715,300	5.0	46	1927.2	664,400	3.7	46	9.11	520,331	520,187	6,587	30,207	6,443	30,208	44	31	20	11
	11/10/09	21:25	3,089.9	716,600	5.0	35	1931.5	665,500	4.3	35	9.42	522,478	522,334	2,147	30,332	2,147	30,332	35	33	20	13
	11/12/09	14:39	3,099.8	718,900	3.9	35	1935.9	667,400	7.2	35	9.54	525,819	525,675	3,341	30,527	3,341	30,527	35	33	20	13
	11/13/09	14:03	3,106.4	720,000	2.8	35	1938.1	668,200	6.1	37	9.38	527,490	527,345	1,671	30,624	1,670	30,624	35	33	20	13

Table A-1. EPA Arsenic Demonstration Project at Pomfret, CT - Daily System Operation Log Sheet (Continued)

Week No.	Date	Time	Well No. 1 Hour meter	Well No. 1 Pump 1 Totalizer	Well No. 1 Calculated Inlet Flowrate	Well No. 1 Well 1 Pressure	Well No. 2 Hour meter	Well No. 2 Pump 2 Totalizer	Well No. 2 Calculated Inlet Flowrate	Well No. 2 Well 2 Pressure	Vessels A & B Instant Flow rate	Vessels A & B Totalizer 1	Vessels A & B Totalizer 2	Throughput Volume Treated Vessel A	Throughput Cum. Bed Volumes Treated Vessel A	Throughput Volume Treated Vessel B	Throughput Cum. Bed Volumes Treated Vessel B	System Pressure Pressure Before pre-filter	System Pressure Inlet Pressure Vessel A	System Pressure Outlet Pressure Vessel A	System Pressure Outlet Pressure Vessel B
			hr	gal	gpm	psi	hr	gal	gpm	psi	gpm	gal	gal	gal	BV	gal	BV	psi	psi	psi	psi
42	11/16/09	4:10	3,116.4	723,300	5.5	38	1947.9	670,700	4.3	39	9.40	533,384	533,239	5,894	30,966	5,894	30,966	36	33	21	13
	11/17/09	11:04	3,119.1	723,900	3.7	36	1949.7	671,100	3.7	38	8.87	534,503	534,358	1,119	31,031	1,119	31,031	35	32	20	13
	11/18/09	8:30	3,121.5	725,000	7.6	36	1953.1	671,900	3.9	38	9.19	536,185	536,039	1,682	31,129	1,681	31,129	35	32	20	13
	11/19/09	3:10	3,126.1	726,400	5.1	40	1957.6	673,100	4.4	40	9.46	538,646	538,501	2,461	31,272	2,462	31,272	38	33	20	12
	11/20/09	3:30	3,130.7	727,900	5.4	40	1967.2	674,200	1.9	40	9.25	541,134	540,989	2,488	31,417	2,488	31,417	39	33	20	12
44	12/1/09	21:10	3,168.1	739,800	5.3	38	1999.5	683,500	4.8	39	9.66	561,130	560,984	19,996	32,580	19,995	32,579	36	35	22	14
	12/2/09	8:40	3,170.2	740,500	5.6	38	2001.6	684,000	4.0	39	9.61	562,316	562,171	1,186	32,648	1,187	32,648	36	35	22	13
45	12/7/09	10:15	3,186.3	745,500	5.2	34	2017.7	687,900	4.0	35	10	570,799	570,654	8,483	493	8,483	493	32	30	20	15
	12/8/09	2:00	3,191.2	747,200	5.8	34	2022.6	689,200	5.8	35	9.7	573,573	573,428	2,774	654	2,774	654	33	30	20	15
	12/9/09	11:22	3,192.9	747,700	4.9	34	2024.3	689,600	14.7	35	10.02	574,559	574,413	986	712	985	712	33	30	20	15
	12/11/09	10:15	3,198.5	749,600	5.7	34	2029.9	691,100	4.5	35	10	577,811	577,666	3,252	901	3,253	901	34	30	20	15
46	12/14/09	14:35	3,209.2	753,200	5.6	35	2040.6	693,800	4.2	35	9.81	583,893	583,748	6,082	1,254	6,082	1,254	32	29	20	14
	12/15/09	14:04	3,212.1	754,100	5.2	35	2043.2	694,600	10.3	35	9.78	585,622	585,513	1,729	1,355	1,765	1,357	32	29	20	14
	12/16/09	15:00	3,215.8	755,200	5.0	35	2046.7	695,400	3.8	35	9.88	587,352	587,278	1,730	1,456	1,765	1,460	33	30	20	15
	12/17/09	8:35	3,219.1	756,100	4.5	35	2049.1	696,200	5.6	35	9.75	589,080	589,044	1,728	1,556	1,766	1,562	33	30	20	15
	12/18/09	9:15	3,221.2	757,200	8.7	35	2052.6	697,000	3.8	35	9.87	590,809	590,633	1,729	1,657	1,589	1,655	35	30	20	15
49	1/4/2010	2:10	3,279.3	776,600	5.6	40	2110.5	711,900	4.5	40	9.63	623,964	623,819	33,155	3,584	33,186	3,584	39	30	20	14
	1/5/2010	3:25	3,282.9	777,700	5.1	42	2114.1	712,800	4.2	42	9.42	625,929	625,784	1,965	3,698	1,965	3,698	41	30	20	14
	1/6/2010	1:12	3,286.5	778,900	5.6	44	2117.7	713,700	4.2	44	9.36	627,895	627,749	1,966	3,813	1,965	3,813	43	29	19	13
	1/7/2010	8:35	3,290.2	780,000	5.0	45	2121.4	714,600	4.1	45	9.23	629,860	629,714	1,965	3,927	1,965	3,927	44	28	19	12
50	1/12/2010	9:30	3,305.4	785,100	5.6	32	2136.6	718,500	5.3	35	9.63	638,615	638,470	8,755	4,436	8,756	4,436	33	30	20	14
	1/13/2010	11:04	3,309.1	786,300	5.4	32	2140.5	719,400	4.3	35	9.75	640,741	640,596	2,126	4,560	2,126	4,560	33	30	20	14
	1/14/2010	10:23	3,312.8	787,600	5.9	32	2143.9	720,400	4.9	35	9.89	642,867	642,722	2,126	4,683	2,126	4,683	33	30	20	14
	1/15/2010	13:42	3,317.1	789,100	5.8	32	2148.2	725,100	18.2	36	9.68	645,349	645,204	2,482	4,828	2,482	4,828	34	30	20	14
52	1/25/2010	13:45	3,351.9	800,500	5.5	35	2183.1	730,300	2.9	35	9.66	664,796	664,651	19,447	5,958	19,447	5,958	33	30	22	15
	1/26/2010	14:02	3,355.1	801,500	5.2	35	2186.3	731,100	4.2	35	9.78	666,617	666,472	1,821	6,064	1,821	6,064	34	30	21	15
	1/27/2010	12:10	3,358.3	802,600	5.7	35	2189.4	731,900	4.3	35	9.87	668,439	668,292	1,822	6,170	1,820	6,170	34	30	21	15
	1/28/2010	13:52	3,361.7	803,700	5.4	35	2192.8	732,800	4.4	35	9.89	670,371	670,224	1,932	6,282	1,932	6,282	35	30	21	15
	1/29/2010		3,365.1	804,800	5.4	35	2196.1	733,700	4.5	35	9.85	672,303	672,156	1,932	6,395	1,932	6,394	35	30	21	15
53	2/1/2010	14:50	3,376.4	808,600	5.6	40	2,207.5	736,600	2.5	40	9.81	678,744	678,597	6,441	6,769	6,441	6,769	33	30	22	15
	2/3/2010	8:50	3,388.1	810,800	3.1	35	2,210.7	738,300	8.9	32	9.76	682,294	682,149	3,550	6,975	3,552	6,975	32	30	21	14
	2/4/2010	9:39	3,392.3	812,200	5.6	34	2,219.2	739,400	2.2	33	9.81	684,756	684,611	2,462	7,119	2,462	7,119	33	31	21	14
	2/5/2010	14:30	3,396.5	813,700	6.0	35	2,223.2	740,500	4.6	35	10.06	687,219	687,074	2,463	7,262	2,463	7,262	34	31	21	15
54	2/9/2010	8:55	3,408.4	817,600	5.5	35	2,231.1	743,500	2.3	35	9.44	694,023	693,877	6,804	7,657	6,803	7,657	34	30	21	13
	2/10/2010	11:55	3,412.6	818,900	5.2	37	2,235.3	744,600	4.4	37	9.38	696,388	696,242	2,365	7,795	2,365	7,795	35	31	20	13
	2/11/2010	13:38	3,416.9	820,200	5.0	39	2,239.6	745,600	3.9	39	9.21	698,752	698,607	2,364	7,932	2,365	7,932	37	30	19	13
	2/12/2010	14:52	3,421.1	821,700	6.0	40	2,243.8	746,700	4.4	40	8.93	701,118	700,972	2,366	8,070	2,365	8,070	38	29	18	13
55	2/16/2010	15:20	3,433.9	825,700	5.2	45	2,256.6	749,800	4.0	45	8.91	701,933	701,786	815	8,117	814	8,117	45	28	19	12
	2/17/2010	11:30	3,438.1	826,900	4.8	35	2,260.7	750,700	3.7	34	9.44	710,013	709,867	8,080	8,587	8,081	8,587	30	30	21	15
56	2/23/2010	15:06	3,460.3	834,300	5.6	35	2,282.8	756,400	4.3	35	9.89	722,699	722,553	12,686	9,325	12,686	9,325	35	32	22	15
	2/24/2010	13:25	3,464.4	835,600	5.3	36	2,287.1	757,400	3.9	35	9.84	725,023	724,877	2,324	9,460	2,324	9,460	35	32	22	15
	2/25/2010	15:17	3,468.5	837,000	5.7	36	2,291.1	758,500	4.6	38	9.81	727,347	727,202	2,324	9,595	2,325	9,595	35	32	22	15
	2/26/2010	9:56	3,470.4	837,600	5.3	36	2,292.9	759,000	4.6	38	9.46	727,389	728,243	42	9,597	1,041	9,655	35	31	21	15

Table A-1. EPA Arsenic Demonstration Project at Pomfret, CT - Daily System Operation Log Sheet (Continued)

Week No.	Date	Time	Well No. 1 Hour meter	Well No. 1 Pump 1 Totalizer	Well No. 1 Calculated Inlet Flowrate	Well No. 1 Well 1 Pressure	Well No. 2 Hour meter	Well No. 2 Pump 2 Totalizer	Well No. 2 Calculated Inlet Flowrate	Well No. 2 Well 2 Pressure	Vessels A & B Instant Flow rate	Vessels A & B Totalizer 1	Vessels A & B Totalizer 2	Throughput Volume Treated Vessel A	Throughput Cum. Bed Volumes Treated Vessel A	Throughput Volume Treated Vessel B	Throughput Cum. Bed Volumes Treated Vessel B	System Pressure Pressure Before pre-filter	System Pressure Inlet Pressure Vessel A	System Pressure Outlet Pressure Vessel A	System Pressure Outlet Pressure Vessel B
			hr	gal	gpm	psi	hr	gal	gpm	psi	gpm	gal	gal	gal	BV	gal	BV	psi	psi	psi	psi
57	3/1/2010	14:24	3,482.8	841,700	5.5	40	2,305.4	762,100	4.1	40	9.44	735,289	735,144	7,900	10,057	6,901	10,057	40	30	20	13
	3/2/2010	12:40	3,486.6	842,900	5.3	42	2,309.3	763,000	3.8	43	8.97	737,333	737,188	2,044	10,175	2,044	10,175	43	29	19	12
	3/3/2010	8:39	3,490.4	844,100	5.3	45	2,313.1	763,900	3.9	45	8.63	739,377	739,232	2,044	10,294	2,044	10,294	43	28	18	12
	3/4/2010	11:54	3,494.7	845,400	5.0	34	2,317.3	765,000	4.4	35	9.46	741,635	741,490	2,258	10,426	2,258	10,426	33	31	21	15
58	3/8/2010	12:43	3,509.6	850,300	5.5	38	2,332.1	768,700	4.2	36	9.83	750,092	749,946	8,457	10,917	8,456	10,917	36	32	21	15
	3/9/2010	2:03	3,512.4	851,200	5.4	40	2,334.9	769,400	4.2	36	9.79	751,734	751,588	1,642	11,013	1,642	11,013	36	32	21	15
	3/10/2010	12:30	3,515.3	852,200	5.7	40	2,337.8	770,200	4.6	38	9.81	753,376	753,231	1,642	11,108	1,643	11,108	38	32	22	15
	3/11/2010	14:48	3,518.9	853,400	5.6	40	2,341.4	771,100	4.2	39	9.76	755,411	755,266	2,035	11,226	2,035	11,226	39	31	21	15
	3/12/2010	15:22	3,522.5	854,600	5.6	40	2,345.1	772,000	4.1	40	9.66	757,447	757,301	2,036	11,345	2,035	11,345	40	31	21	15
59	3/18/2010	13:30	3,543.7	861,200	5.2	50	2,366.2	777,200	4.1	50	9.16	768,874	768,728	11,427	12,009	11,427	12,009	45	30	20	13
	3/19/2010	14:00	3,548.7	862,700	5.0	36	2,371.0	778,300	3.8	38	9.7	771,321	771,321	2,447	12,151	2,593	12,160	35	33	23	15
60	3/22/2010	2:40	3,558.4	866,000	5.7	36	2,380.9	780,900	4.4	38	9.96	777,060	776,913	5,739	12,485	5,592	12,485	35	33	23	15
	3/23/2010	9:00	3,560.4	866,600	5.0	38	2,382.8	781,400	4.4	39	9.93	778,174	778,029	1,114	12,550	1,116	12,550	36	33	22	15
	3/24/2010	12:00	3,563.5	867,700	5.9	39	2,385.9	782,200	4.3	40	9.91	779,999	779,854	1,825	12,656	1,825	12,656	37	33	22	15
62	4/5/2010	13:20	3,605.1	880,700	5.2	55	2,427.4	792,300	4.1	55	8.35	802,505	802,360	22,506	13,964	22,506	13,964	50	25	16	10
	4/6/2010	11:20	3,609.4	881,900	4.7	35	2,431.5	793,200	3.7	35	9.63	804,555	804,410	2,050	14,084	2,050	14,084	35	33	23	16
	4/7/2010	10:10	3,613.1	883,200	5.9	35	2,435.4	794,200	4.3	35	9.81	806,842	806,697	2,287	14,217	2,287	14,217	35	32	22	16
	4/8/2010	13:55	3,616.6	884,400	5.7	36	2,438.9	795,100	4.3	37	9.76	808,875	808,729	2,033	14,335	2,032	14,335	35	33	22	16
	4/9/2010	14:20	3,620.2	885,600	5.6	37	2,442.5	796,100	4.6	38	10.17	810,908	810,762	2,033	14,453	2,033	14,453	35	33	23	16
63	4/12/2010	8:10	3,630.7	889,000	5.4	38	2,453.5	798,500	3.6	39	9.97	816,896	816,750	5,988	14,801	5,988	14,801	38	33	23	16
	4/13/2010	9:02	3,634.2	890,100	5.2	39	2,457.1	799,300	3.7	39	9.91	818,892	818,747	1,996	14,917	1,997	14,917	38	32	23	16
	4/14/2010	8:55	3,638.4	891,300	4.8	40	2,460.6	800,100	3.8	40	9.87	820,889	820,743	1,997	15,033	1,996	15,033	38	32	23	15
	4/15/2010	8:45	3,641.1	892,500	7.4	40	2,463.3	801,400	8.0	40	9.85	822,884	822,738	1,995	15,149	1,995	15,149	38	32	22	15
64	4/19/2010	13:06	3,655.3	897,000	5.3	45	2,478	804,900	4.1	45	9.36	830,753	830,607	7,869	15,607	7,869	15,607	45	40	20	14
	4/20/2010	11:08	3,658.1	897,900	5.4	45	2,480	805,600	4.3	45	8.75	832,214	832,068	1,461	15,692	1,461	15,692	44	27	18	12
	4/21/2010	10:42	3,661.5	898,900	4.9	48	2,484	806,300	3.4	48	8.52	833,914	833,795	1,700	15,791	1,727	15,792	45	25	16	11
	4/22/2010	11:25	3,664.8	899,800	4.5	50	2,487	807,000	3.5	50	8.38	835,667	835,521	1,753	15,893	1,726	15,892	48	23	15	11
	4/23/2010	10:40	3,668.2	900,900	5.4	52	2,490	807,900	4.3	53	8.08	837,394	837,248	1,727	15,993	1,727	15,993	50	22	15	10
65	4/26/2010	13:12	3,680.9	905,400	5.9	38	2,503	811,300	4.5	38	9.81	845,691	845,546	8,297	16,475	8,298	16,475	39	33	22	15
	4/27/2010	15:15	3,683.7	906,000	3.6	40	2,506	811,900	3.7	40	9.76	846,235	846,090	544	16,507	544	16,507	38	32	22	15
	4/28/2010	14:06	3,686.4	906,600	3.7	40	2,509	812,600	4.3	40	9.58	846,779	846,634	544	16,539	544	16,539	37	32	21	14
	4/29/2010	15:48	3,689.2	907,200	3.6	40	2,511	813,200	3.6	40	9.12	847,323	847,178	544	16,570	544	16,570	35	30	20	13
66	5/3/2010	13:35	3,705	912,600	5.8	45	2,527	817,000	4.1	45	9.19	857,737	857,591	10,414	17,176	10,413	17,176	45	28	20	12
68	5/18/2010	9:25	3,764	930,900	5.2	50	2,585	831,300	4.1	50	9.06	889,460	889,315	31,723	19,020	31,724	19,020	NR	NR	NR	NR
	5/19/2010	2:10	3,767	932,000	5.1	35	2,589	832,100	3.6	35	9.87	891,311	891,166	1,851	19,128	1,851	19,128	35	32	22	15
	5/20/2010	9:45	3,771	932,900	4.1	35	2,593	832,900	3.7	35	9.89	893,163	893,018	1,852	19,235	1,852	19,235	35	32	22	15
	5/21/2010	3:15	3,775	934,400	6.6	35	2,597	833,900	4.4	35	10	895,370	895,224	2,207	19,364	2,206	19,364	35	32	22	15
69	5/24/2010	4:10	3,785	937,700	5.6	36	2,606	836,500	4.4	38	9.89	901,077	900,932	5,707	19,695	5,708	19,695	36	32	22	15
	5/25/2010	2:45	3,787	938,300	5.3	36	2,608	836,900	3.5	38	9.83	902,157	902,012	1,080	19,758	1,080	19,758	36	32	22	15
	5/26/2010	3:30	3,789	938,900	5.0	36	2,610	837,400	4.4	38	9.76	903,238	903,093	1,081	19,821	1,081	19,821	36	32	21	15
	5/27/2010	10:45	3,795	940,900	5.5	36	2,616	839,000	4.4	38	9.1	906,670	906,525	3,432	20,021	3,432	20,021	36	29	20	13
	5/28/2010	14:30	3,799	942,300	5.4	40	2,621	840,000	3.9	40	9.66	909,090	908,943	2,420	20,161	2,418	20,161	39	30	21	14

Table A-1. EPA Arsenic Demonstration Project at Pomfret, CT - Daily System Operation Log Sheet (Continued)

			Well No. 1				Well No. 2				Vessels A & B			Throughput				System Pressure			
Week No.	Date	Time	Hour meter	Pump 1 Totalizer	Calculated Inlet Flowrate	Well 1 Pressure	Hour meter	Pump 2 Totalizer	Calculated Inlet Flowrate	Well 2 Pressure	Instant Flow rate	Totalizer 1	Totalizer 2	Volume Treated Vessel A	Cum. Bed Volumes Treated Vessel A	Volume Treated Vessel B	Cum. Bed Volumes Treated Vessel B	Pressure Before pre-filter	Inlet Pressure Vessel A	Outlet Pressure Vessel A	Outlet Pressure Vessel B
			hr	gal	gpm	psi	hr	gal	gpm	psi	gpm	gal	gal	gal	BV	gal	BV	psi	psi	psi	psi
71	6/8/2010	14:14	3,836	954,600	5.5	40	2,658	849,500	4.3	40	9.85	930,333	930,188	21,243	21,396	21,245	21,396	38	33	22	15
	6/9/2010	13:49	3,839	955,400	5.3	40	2,660	850,100	4.0	40	9.78	931,757	931,612	1,424	21,479	1,424	21,479	39	32	21	14
	6/10/2010	9:00	3,841	956,200	5.3	40	2,663	850,800	4.7	40	9.55	933,182	933,037	1,425	21,562	1,425	21,562	39	31	21	14
	6/11/2010	15:15	3,846	957,800	5.3	42	2,668	852,000	4.1	43	9.63	935,870	935,725	2,688	21,718	2,688	21,718	41	30	20	13
72	6/14/2010	15:21	3,856	960,700	5.1	46	2,677	854,300	4.0	47	9.34	940,997	940,851	5,127	22,016	5,126	22,016	44	30	20	13
	6/15/2010	11:00	3,858	961,400	5.3	35	2,679	854,800	3.8	35	9.96	942,255	942,109	1,258	22,089	1,258	22,089	35	33	22	15
	6/16/2010	12:33	3,861	962,600	5.7	35	2,683	855,700	4.5	36	9.89	944,257	944,111	2,002	22,206	2,002	22,206	35	33	22	15
	6/17/2010	10:45	3,865	963,800	5.9	36	2,686	856,600	4.2	38	10.04	946,259	946,114	2,002	22,322	2,003	22,322	35	33	22	15
73	6/22/2010	14:15	3880.6	969,000	5.4	40	2,702	860,700	4.3	40	9.72	955,404	955,259	9,145	22,854	9,145	22,854	37	30	21	15
	6/23/2010	13:42	3885.3	970,500	5.3	40	2,707	861,800	3.9	41	9.7	958,024	957,879	2,620	23,006	2,620	23,006	39	30	20	14
	6/24/2010	14:55	3890.1	972,000	5.2	40	2,712	863,000	4.3	42	9.59	960,645	960,500	2,621	23,159	2,621	23,159	40	30	20	14
	6/25/2010	14:43	3893.2	973,100	5.9	35	2,715	863,800	4.3	35	9.46	962,370	962,225	1,725	23,259	1,725	23,259	34	33	22	15
74	6/29/2010	9:10	3967.5	983,800	2.4	35	2,718	872,000	40.2	35	9.85	979,612	979,466	17,242	24,261	17,241	24,261	34	32	21	15
	7/2/2010	14:25	3978.4	987,400	5.5	10	2,729	874,800	4.3	13	6.31	985,867	985,721	6,255	24,625	6,255	24,625	19	15	10	7
75	7/5/2010	12:55	3992.4	992,000	5.5	38	2,743	878,300	4.2	40	9.46	993,797	993,657	7,930	25,086	7,936	25,086	36	30	20	14
	7/6/2010	13:45	3995.6	993,000	5.2	38	2,746	879,100	4.2	39	9.58	995,616	995,473	1,819	25,192	1,816	25,192	36	30	20	14
	7/7/2010	14:20	3998.9	994,100	5.6	40	2,749	879,900	4.0	40	9.25	997,436	997,289	1,820	25,298	1,816	25,298	37	30	20	15
	7/8/2010	14:25	4002.1	995,200	5.7	40	2,753	880,700	4.0	40	9.12	999,256	999,105	1,820	25,403	1,816	25,403	37	30	20	15
76	7/14/2010	8:20	4019.7	1,000,600	5.1	35	2,770	884,900	4.0	35	9.33	1,008,654	1,008,509	9,398	25,950	9,404	25,950	35	34	24	16
	7/15/2010	13:35	4024.4	1,002,200	5.7	35	2,775	886,100	4.3	36	10.03	1,011,301	1,011,156	2,647	26,104	2,647	26,104	35	34	24	16
	7/16/2010	14:10	4029.1	1,003,800	5.7	35	2,780	887,300	4.3	36	9.87	1,013,803	1,013,803	2,502	26,249	2,647	26,258	35	34	24	16
77	7/19/2010		4036.4	1,006,200	5.5	36	2,787	889,200	4.3	36	9.78	1,018,186	1,018,040	4,383	26,504	4,237	26,504	33	30	22	15
	7/20/2010	8:35	4043.6	1,008,600	5.6	35	2,794	891,000	4.2	36	9.51	1,022,424	1,022,278	4,238	26,750	4,238	26,750	33	30	22	15
	7/21/2010	1:56	4046.9	1,009,700	5.6	35	2,797	891,800	4.2	36	9.75	1,024,320	1,024,174	1,896	26,861	1,896	26,861	34	32	22	15
	7/22/2010	2:30	4050.1	1,010,800	5.7	35	2,801	892,700	4.7	36	9.83	1,026,216	1,026,071	1,896	26,971	1,897	26,971	35	33	22	15
	7/23/2010	9:45	4053.4	1,011,900	5.6	35	2,804	893,500	4.2	36	9.91	1,028,113	1,027,967	1,897	27,081	1,896	27,081	35	34	23	16
78	7/26/2010	14:39	4063.9	1,015,500	5.7	35	2814.3	896,200	4.2	37	10.04	1,034,275	1,034,130	6,162	27,439	6,163	27,439	35	34	25	17
	7/27/2010	12:56	4067.4	1,016,600	5.2	35	2817.7	897,100	4.4	37	9.75	1,036,281	1,036,136	2,006	27,556	2,006	27,556	35	34	23	17
	7/28/2010	13:12	4070.9	1,017,800	5.7	35	2821.1	898,000	4.4	36	9.93	1,038,288	1,038,142	2,007	27,673	2,006	27,673	35	33	22	16
	7/29/2010	14:42	4074.3	1,018,900	5.4	35	2824.6	898,900	4.3	36	9.81	1,040,295	1,040,149	2,007	27,789	2,007	27,789	35	33	22	15
79	8/2/2010	13:55	4089.4	1,024,000	5.6	38	2839.6	902,800	4.3	39	10.04	1,049,085	1,048,939	8,790	28,301	8,790	28,300	36	35	24	17
	8/3/2010	14:10	4093.1	1,025,200	5.4	37	2843.4	903,700	3.9	38	9.87	1,051,264	1,051,118	2,179	28,427	2,179	28,427	36	34	23	16
	8/4/2010	13:59	4096.9	1,026,500	5.7	37	2847.2	904,700	4.4	38	9.63	1,053,443	1,053,298	2,179	28,554	2,180	28,554	35	33	22	15
	8/5/2010	13:49	4100.3	1,027,700	5.9	38	2850.6	905,500	3.9	39	9.91	1,055,450	1,055,303	2,007	28,671	2,005	28,670	36	33	24	16
80	8/9/2010	11:22	4108.1	1,030,400	5.8	39	2858.6	907,600	4.4	40	9.87	1,060,098	1,059,953	4,648	28,941	4,650	28,941	36	34	23	16
	8/10/2010	10:45	4112.4	1,031,700	5.0	39	2862.7	908,600	4.1	40	9.93	1,062,421	1,062,275	2,323	29,076	2,322	29,076	36	34	23	16
	8/11/2010	13:23	4116.0	1,032,900	5.6	39	2866.2	909,500	4.3	40	9.083	1,064,478	1,064,332	2,057	29,195	2,057	29,195	36	34	23	16
	8/12/2010	13:55	4119.5	1,034,100	5.7	39	2869.7	910,400	4.3	40	9.92	1,066,535	1,066,389	2,057	29,315	2,057	29,315	37	35	22	16
	8/13/2010	14:36	4123.1	1,035,300	5.6	39	2873.3	911,300	4.2	40	9.98	1,068,594	1,068,448	2,059	29,435	2,059	29,435	37	35	22	16
81	8/18/2010	15:30	4140.4	1041100	5.6	36	2890.7	915700	4.2	38	10.04	1,078,603	1,078,458	10,009	30,017	10,010	30,017	35	35	24	17
	8/19/2010		4143.1	1042000	5.6	35	2893.2	916400	4.7	36	9.85	1,080,119	1,079,974	1,516	30,105	1,516	30,105	35	34	23	16
	8/20/2010	15:35	4145.6	1042900	6.0	35	2895.8	917100	4.5	36	9.71	1,081,636	1,081,490	1,517	30,193	1,516	30,193	35	33	22	15

Table A-1. EPA Arsenic Demonstration Project at Pomfret, CT - Daily System Operation Log Sheet (Continued)

Week No.	Date	Time	Well No. 1				Well No. 2				Vessels A & B			Throughput				System Pressure			
			Hour meter	Pump 1 Totalizer	Calculated Inlet Flowrate	Well 1 Pressure	Hour meter	Pump 2 Totalizer	Calculated Inlet Flowrate	Well 2 Pressure	Instant Flow rate	Totalizer 1	Totalizer 2	Volume Treated Vessel A	Cum. Bed Volumes Treated Vessel A	Volume Treated Vessel B	Cum. Bed Volumes Treated Vessel B	Pressure Before pre-filter	Inlet Pressure Vessel A	Outlet Pressure Vessel A	Outlet Pressure Vessel B
			hr	gal	gpm	psi	hr	gal	gpm	psi	gpm	gal	gal	gal	BV	gal	BV	psi	psi	psi	psi
82	8/23/2010	13:32	4155.9	1,046,500	5.7	35	2906.1	919,800	4.3	35	9.85	1,087,583	1,087,438	18,989	30,539	18,990	30,539	34	30	22	15
	8/24/2010	12:55	4159.2	1,047,500	5.1	35	2909.4	920,600	4.0	35	9.77	1,089,535	1,089,420	1,952	30,652	1,982	30,654	33	30	22	15
	8/25/2010	12:00	4162.6	1,048,600	5.4	35	2912.8	921,400	3.9	35	9.42	1,091,547	1,091,402	2,012	30,769	1,982	30,769	33	30	22	15
	8/26/2010	14:10	4166.1	1,049,700	5.2	35	2916.2	922,500	5.4	35	9.76	1,093,529	1,093,384	1,982	30,884	1,982	30,884	33	30	22	15
	8/27/2010	13:48	4169.3	1,050,700	5.2	35	2919.5	923,500	5.1	35	9.97	1,095,511	1,095,266	1,982	31,000	1,882	30,994	33	30	22	15
83	8/30/2010	15:47	4181.1	1,054,700	5.6	35	2939.9	925,700	1.8	37	9.81	1,102,101	1,101,956	6,590	31,383	6,690	31,383	35	34	22	15
	8/31/2010	6:45	4184.5	1,056,000	6.4	35	2942.5	927,000	8.3	37	9.78	1,104,152	1,104,152	2,051	31,502	2,196	31,511	35	34	22	15
	9/1/2010	16:23	4187.9	1,057,300	6.4	36	2945.1	928,300	8.3	38	8.99	1,105,395	1,105,250	1,243	31,574	1,098	31,574	36	35	23	15
	9/2/2010	15:56	4191.1	1,058,600	6.8	36	2947.6	929,600	8.7	38	9.95	1,106,493	1,106,348	1,098	31,638	1,098	31,638	36	35	23	15
84	9/7/2010	10:00	4207.8	1,063,800	5.2	38	2957.9	933,000	5.5	40	10.06	1,117,837	1,117,691	11,344	32,298	11,343	32,298	36	35	25	16
85	9/15/2010	14:43	4236.1	1,073,200	5.5	38	2986.2	940,100	4.2	40	8.12	1,134,079	1,133,933	16,242	33,242	16,242	33,242	36	35	25	18
	9/16/2010	15:10	4239.9	1,074,500	5.7	38	2990.1	941,100	4.3	40	9.55	1,136,297	1,136,151	2,218	33,371	2,218	33,371	36	35	25	18
	9/17/2010	14:50	4243.8	1,075,800	5.6	38	2993.9	942,100	4.4	40	9.98	1,138,515	1,138,370	2,218	33,500	2,219	33,500	37	35	25	18

APPENDIX B

ANALYTICAL DATA

Table B-1. Analytical Results from Treatment Plant Sampling at Pomfret, CT

Sampling Date		03/11/09				03/26/09				04/08/09				04/23/09				05/06/09			
Sampling Location Parameter	Unit	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS
Bed Volume	10^3	-	3.6			-	5.2			-	6.5			-	8.0			-	9.3		
Alkalinity (as $CaCO_3$)	mg/L	53.3 -	49.1 -	49.1 -	46.9 -	46.4 -	46.4 -	44.3 -	48.5 -	46.2 -	48.6 -	48.6 -	50.9 -	48.2 -	48.2 -	48.2 -	48.2 -	50.9 -	48.5 -	49.7 -	49.7 -
Fluoride	mg/L	0.3	0.2	0.3	0.3	-	-	-	-	0.2	0.3	0.2	0.3	-	-	-	-	0.3	0.3	0.3	0.3
Sulfate	mg/L	19.1	20.4	20.7	20.4	-	-	-	-	20.3	20.6	20.8	21.0	-	-	-	-	21.7	19.9	20.5	21.9
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	<0.05
Total P (as P)	µg/L	229 -	48.3 -	<10 -	<10 -	159 -	116 -	<10 -	<10 -	168 -	<10 -	<10 -	<10 -	192 -	188 -	21.0 -	11.6 -	172 -	185 -	119 -	84.9 -
Silica (as SiO_2)	mg/L	14.4 -	15.0 -	14.7 -	14.7 -	13.9 -	13.5 -	14.1 -	14.1 -	14.2 -	14.0 -	14.3 -	14.5 -	14.2 -	14.1 -	15.9 -	15.8 -	16.6 -	16.2 -	16.5 -	16.1 -
Turbidity	NTU	0.3 -	0.2 -	0.2 -	0.1 -	1.5 -	0.7 -	0.1 -	0.9 -	1.1 -	0.3 -	0.3 -	0.2 -	4.5 -	1.2 -	2.0 -	0.4 -	2.0 -	0.3 -	0.4 -	0.3 -
pH	S.U.	7.9	7.9	7.5	7.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Temperature	°C	18.5	10.3	17.9	18.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DO	mg/L	2.8	2.0	2.0	4.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ORP	mV	429	409	438	456	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Hardness (as $CaCO_3$)	mg/L	65.5	65.3	65.5	65.3	-	-	-	-	51.4	50.5	52.0	50.0	-	-	-	-	63.3	72.5	71.6	75.7
Ca Hardness (as $CaCO_3$)	mg/L	53.6	52.2	52.0	53.3	-	-	-	-	44.3	43.7	44.2	42.4	-	-	-	-	55.7	63.8	62.9	66.5
Mg Hardness (as $CaCO_3$)	mg/L	11.9	13.0	13.6	12.0	-	-	-	-	7.1	6.8	7.8	7.6	-	-	-	-	7.5	8.7	8.7	9.2
As (total)	µg/L	26.5 -	1.0 -	0.2 -	1.5 -	24.0 -	1.4 -	0.1 -	1.5 -	22.4 -	3.5 -	<0.1	0.9 -	26.8 -	3.7 -	0.1 -	1.5 -	23.1 -	5.0 -	0.2 -	1.9 -
As (soluble)	µg/L	26.9	1.0	0.2	1.5	-	-	-	-	23.0	4.0	0.3	4.2	-	-	-	-	22.5	5.1	0.2	1.8
As (particulate)	µg/L	<0.1	<0.1	<0.1	<0.1	-	-	-	-	<0.1	<0.1	<0.1	<0.1	-	-	-	-	0.6	<0.1	<0.1	<0.1
As (III)	µg/L	4.2	0.9	0.4	0.3	-	-	-	-	3.5	0.3	0.1	0.1	-	-	-	-	4.0	0.4	0.2	0.1
As (V)	µg/L	22.7	0.1	<0.1	1.2	-	-	-	-	19.5	3.6	0.2	4.1	-	-	-	-	18.5	4.7	<0.1	1.7
Fe (total)	µg/L	36 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	36 -	<25 -	<25	<25 -	74 -	<25 -	<25 -	<25 -	58 -	<25 -	<25 -	<25 -
Fe (soluble)	µg/L	<25	<25	<25	<25	-	-	-	-	<25	<25	<25	<25	-	-	-	-	<25	<25	<25	<25
Mn (total)	µg/L	16.7 -	2.3 -	1.5 -	0.7 -	20.2 -	2.6 -	0.8 -	0.3 -	22.8 -	6.7 -	0.5	0.1 -	55.3 -	2.7 -	0.6 -	0.1 -	46.7 -	2.0 -	0.6 -	0.6 -
Mn (soluble)	µg/L	11.4	1.6	0.9	0.1	-	-	-	-	6.8	0.5	0.4	0.3	-	-	-	-	9.7	0.4	0.5	0.1
Ti (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table B-1. Analytical Results from Treatment Plant Sampling at Pomfret, CT (Continued)

Sampling Date		05/20/09				06/03/09[a]				06/17/09				07/01/09				07/15/09[b]			
Sampling Location Parameter	Unit	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS
Bed Volume	10^3	-	10.8			-	12.9			-	14.0			-	16.0			-	17.7		
Alkalinity (as $CaCO_3$)	mg/L	49.2 -	50.9 -	47.6 -	49.2 -	50.6 -	50.6 -	51.9 -	50.6 -	51.3 -	51.3 -	49.2 -	51.3 -	51.3 -	49.0 -	51.3 -	51.3 -	47.3 49.7	49.7 45	49.7 49.7	49.7 -
Fluoride	mg/L	-	-	-	-	0.2	0.2	0.4	0.2	-	-	-	-	0.2	0.3	0.2	0.3	-	-	-	-
Sulfate	mg/L	-	-	-	-	20.1	20.7	21.2	20.3	-	-	-	-	25.4	20.8	21.9	20.9	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-
Total P (as P)	µg/L	178 -	185 -	152 -	139 -	184 -	195 -	170 -	160 -	177 -	172 -	167 -	162 -	166 -	111 -	147 -	166 -	171 196	142 165	130 129	148 149
Silica (as SiO_2)	mg/L	15.6 -	15.5 -	16.0 -	15.7 -	16 -	15.8 -	15.6 -	15.8 -	15.1 -	15.2 -	15.1 -	15.3 -	14.9 -	15.6 -	15.2 -	14.8 -	15.3 15.2	15.3 15.5	15.2 15.2	15.4 15.5
Turbidity	NTU	1.3 -	0.6 -	0.2 -	0.3 -	1.9 -	0.7 -	1.1 -	0.7 -	1.6 -	1.2 -	0.8 -	0.4 -	4.4 -	0.8 -	1.2 -	0.7 -	1.1 0.7	2.1 0.4	2.0 0.1	<0.1 <0.1
pH	S.U.	NA	NA	NA	NA	7.9	7.9	7.9	7.9	NA	NA	NA	NA	NA	NA	NA	NA	7.8	7.8	7.8	7.9
Temperature	°C	NA	NA	NA	NA	25.0	25.0	25.0	25.0	NA	NA	NA	NA	NA	NA	NA	NA	25.0	25.0	25.0	25.0
DO	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ORP	mV	NA	NA	NA	NA	488	451	451	445	NA	NA	NA	NA	NA	NA	NA	NA	414	425	426	421
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	54.5	57.1	55.6	56.7	-	-	-	-	63.5	61.4	63.4	64.5	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	55.9	57.6	58.5	57.6	47.4	49.4	48.1	49.4					55.5	54.1	55.5	56.5	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	7.2	7.6	7.5	7.3	-	-	-	-	8.0	7.4	7.9	8.0	-	-	-	-
As (total)	µg/L	25.2 -	7.1 -	<0.1 -	1.5 -	24.1 -	8.8 -	<0.1 -	1.2 -	24.6 -	11.4 -	<0.1 -	1.1 -	24.1 -	9.7 -	0.2 -	0.9 -	29.4 29.1	14.3 14.9	0.7 0.7	1.9 1.9
As (soluble)	µg/L	-	-	-	-	23.9	9.3	0.2	1.4	-	-	-	-	22.8	9.7	0.2	0.8	-	-	-	-
As (particulate)	µg/L	-	-	-	-	0.2	<0.1	<0.1	<0.1	-	-	-	-	1.3	<0.1	<0.1	0.1	-	-	-	-
As (III)	µg/L	-	-	-	-	4.7	0.2	0.1	<0.1	-	-	-	-	5.7	0.2	<0.1	<0.1	-	-	-	-
As (V)	µg/L	-	-	-	-	19.3	9.0	<0.1	1.3	-	-	-	-	17.1	9.6	<0.1	0.7	-	-	-	-
Fe (total)	µg/L	36 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	37 -	<25 -	<25 -	<25 -	36 -	<25 -	<25 -	<25 -	<25 25	<25 <25	<25 <25	<25 <25
Fe (soluble)	µg/L	-	-	-	-	<25	<25	<25	<25	-	-	-	-	<25	<25	<25	<25	-	-	-	-
Mn (total)	µg/L	34.5 -	1.2 -	0.5 -	0.3 -	19.9 -	0.8 -	0.4 -	0.6 -	22.9 -	0.5 -	0.4 -	0.5 -	19.5 -	<0.1 -	<0.1 -	<0.1 -	29.9 30.4	0.6 0.7	0.8 0.7	0.6 0.6
Mn (soluble)	µg/L	-	-	-	-	8.1	0.3	0.4	0.1	-	-	-	-	9.9	<0.1	<0.1	<0.1	-	-	-	-
Ti (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				

Table B-1. Analytical Results from Treatment Plant Sampling at Pomfret, CT (Continued)

Sampling Date		07/30/09				08/12/09				08/26/09				09/09/09[a]				09/23/09			
Sampling Location Parameter	Unit	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS
Bed Volume	10^3	-	19.3			-	20.7			-	22.2			-	23.7			-	25.1[b]		
Alkalinity (as $CaCO_3$)	mg/L	48.0 -	48.0 -	49.1 -	49.1 -	- -	- -	- -	- -	49.0 -	50.1 -	50.1 -	51.3 -	51.9 -	53.9 -	47.9 -	49.9 -	53.7 -	48.1 -	50 -	51.9 -
Fluoride	mg/L	0.3	0.3	0.2	0.4	-	-	-	-	0.2	0.2	0.3	0.2	-	-	-	-	0.3	0.2	0.3	0.2
Sulfate	mg/L	21.1	20.4	20.1	21.5	-	-	-	-	20.3	21.1	20.7	21.4	-	-	-	-	19.5	19.6	20.1	18.8
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	0.1	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	<0.05
Total P (as P)	µg/L	247 -	252 -	228 -	183 -	182 -	178 -	172 -	168 -	181 -	179 -	175 -	163 -	172 -	170 -	171 -	164 -	272 -	157 -	157 -	157 -
Silica (as SiO_2)	mg/L	13.8 -	14.8 -	14.9 -	15.1 -	- -	- -	- -	14.8 -	15.4 -	16.1 -	15.9 -	15.2 -	15.8 -	16.1 -	16.1 -	13.3 -	16.1 -	13.9 -	13.7 -	14.1 -
Turbidity	NTU	3.3 -	0.4 -	2.3 -	2.4 -	- -	- -	- -	1.5 -	1.6 -	4.2 -	0.2 -	0.9 -	0.5 -	0.6 -	1.0 -	0.3 -	2.8 -	0.1 -	1.8 -	0.2 -
pH	S.U.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.9[c]	8.0	8.0	8.0	8.2	-	-	-	-
Temperature	°C	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DO	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ORP	mV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Hardness (as $CaCO_3$)	mg/L	49.1	52.7	54.2	50.2	-	-	-	-	41.2	43.8	45.9	44.5	-	-	-	-	56.3	55.7	56.1	56.5
Ca Hardness (as $CaCO_3$)	mg/L	38.8	41.5	42.6	39.8	-	-	-	-	34.8	37.1	38.7	37.4	-	-	-	-	47.5	46.9	47.3	47.8
Mg Hardness (as $CaCO_3$)	mg/L	10.3	11.2	11.6	10.4	-	-	-	-	6.4	6.7	7.2	7.1	-	-	-	-	8.9	8.7	8.8	8.7
As (total)	µg/L	25.0 -	18.2 -	<0.1 -	<0.1 -	25.8 -	19.0 -	1.9 -	2.1 -	23.6 -	17.1 -	2.6 -	2.5 -	25.3 -	17.1 -	2.8 -	2.8 -	28.9 -	19.0 -	6.2 -	6.5 -
As (soluble)	µg/L	25.5	17.9	<0.1	<0.1	-	-	-	-	23.0	17.4	2.9	2.6	-	-	-	-	24.0	19.0	6.2	6.3
As (particulate)	µg/L	<0.1	0.3	<0.1	<0.1	-	-	-	-	0.6	<0.1	<0.1	<0.1	-	-	-	-	4.9	<0.1	<0.1	0.2
As (III)	µg/L	<0.1	<0.1	<0.1	<0.1	-	-	-	-	5.3	0.3	0.4	0.2	-	-	-	-	1.2	0.2	0.1	0.2
As (V)	µg/L	25.4	17.8	<0.1	<0.1	-	-	-	-	17.7	17.1	2.5	2.5	-	-	-	-	22.8	18.7	6.0	6.2
Fe (total)	µg/L	78 -	<25 -	<25 -	<25 -	78 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	166 -	<25 -	<25 -	<25 -	1,232 -	<25 -	<25 -	<25 -
Fe (soluble)	µg/L	<25	<25	<25	<25	-	-	-	-	<25	<25	<25	<25	-	-	-	-	<25	<25	<25	<25
Mn (total)	µg/L	33.9 -	0.7 -	0.5 -	2.4 -	38.0 -	1.1 -	0.6 -	0.2 -	23.0 -	1.3 -	0.4 -	<0.1 -	102 -	0.5 -	0.3 -	0.7 -	581 -	0.4 -	3.3 -	0.6 -
Mn (soluble)	µg/L	10.5	0.2	0.4	0.3	-	-	-	-	9.1	0.2	0.3	<0.1	-	-	-	-	3.6	0.1	0.2	0.4
Ti (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table B-1. Analytical Results from Treatment Plant Sampling at Pomfret, CT (Continued)

Sampling Date		10/08/09				10/21/09				11/05/09				11/18/09				12/02/09			
Sampling Location Parameter	Unit	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS
Bed Volume	10^3	-	26.8			-	28.2			-	29.8			-	31.1			-	32.6		
Alkalinity (as $CaCO_3$)	mg/L	52.8 56.6	52.8 49.1	50.9 52.8	50.9 47.2	50.6 -	48.6 -	52.7 -	50.6 -	50.9 -	48.6 -	53.2 -	55.5 -	56.7 -	52.1 -	54.4 -	52.1 -	51.1 -	48.9 -	53.3 -	55.6 -
Fluoride	mg/L	-	-	-	-	0.2	0.3	0.4	0.4	-	-	-	-	0.2	0.2	0.4	0.2	-	-	-	-
Sulfate	mg/L	-	-	-	-	17.9	20	23.2	19.7	-	-	-	-	19.7	19.9	19.5	19.5	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-
Total P (as P)	µg/L	147 148	173 171	172 167	155 161	135 -	134 -	129 -	121 -	187 -	179 -	172 -	136 -	133 -	123 -	139 -	139 -	166 -	174 -	171 -	166 -
Silica (as SiO_2)	mg/L	14.5 14.5	14.5 14.6	15 14.7	14.2 14.3	15.4 -	15.5 -	15.5 -	15.3 -	14.6 -	14.1 -	14.1 -	14.3 -	15.2 -	15.5 -	15.4 -	15.2 -	15.8 -	15.7 -	15.9 -	15.5 -
Turbidity	NTU	1.6 1.2	0.5 1.0	0.5 1.0	0.4 0.5	6.2 -	2.6 -	5.0 -	2.6 -	1.2 -	0.6 -	0.8 -	0.3 -	1.2 -	1.1 -	1.0 -	0.3 -	1.8 -	0.8 -	0.4 -	0.1 -
pH	S.U.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Temperature	°C	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DO	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ORP	mV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	62.5	65.4	65.7	62.5	-	-	-	-	59.0	57.7	58.3	57.5	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	54.7	57.8	58.2	55.2	-	-	-	-	50.5	49.3	49.8	49.2	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	7.8	7.6	7.5	7.3	-	-	-	-	8.5	8.3	8.5	8.2	-	-	-	-
As (total)	µg/L	24.2 24.5	20.1 20.2	7.7 7.7	7.0 6.9	24.1 -	19.9 -	8.8 -	8.2 -	25.4 -	20.9 -	10.8 -	8.2 -	23.4 -	19.8 -	12.8 -	11.1 -	24.5 -	21.8 -	13.4 -	12.3 -
As (soluble)	µg/L	-	-	-	-	23.4	19.2	8.9	8.5	-	-	-	-	23.5	19.3	12.5	11.2	-	-	-	-
As (particulate)	µg/L	-	-	-	-	0.8	0.7	<0.1	<0.1	-	-	-	-	<0.1	0.5	0.3	<0.1	-	-	-	-
As (III)	µg/L	-	-	-	-	1.0	<0.1	<0.1	<0.1	-	-	-	-	1.8	0.3	0.2	0.2	-	-	-	-
As (V)	µg/L	-	-	-	-	22.3	19.1	8.8	8.4	-	-	-	-	21.7	19.0	12.2	11.0	-	-	-	-
Fe (total)	µg/L	38 37	<25 <25	<25 <25	<25 <25	<25 -	<25 -	<25 -	<25 -	35 -	<25 -	<25 -	<25 -	28 -	<25 -	<25 -	<25 -	48.0 -	<25 -	<25 -	<25 -
Fe (soluble)	µg/L	-	-	-	-	<25	<25	<25	<25	-	-	-	-	<25	<25	<25	<25	-	-	-	-
Mn (total)	µg/L	20.8 24.0	12.0 11.8	1.9 1.8	1.5 0.8	18.7 -	1.8 -	<0.1 -	<0.1 -	23.3 -	0.3 -	<0.1 -	1.6 -	22.7 -	1.0 -	0.3 -	0.2 -	43.5 -	1.7 -	0.5 -	0.2 -
Mn (soluble)	µg/L	-	-	-	-	6.1	<0.1	<0.1	<0.1	-	-	-	-	6.4	0.2	0.2	0.2	-	-	-	-
Ti (total)	µg/L					-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table B-1. Analytical Results from Treatment Plant Sampling at Pomfret, CT (Continued)

Sampling Date		12/16/09[(a)]				01/07/10				01/20/10				02/03/10				02/18/10			
Sampling Location Parameter	Unit	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS
Bed Volume	10^3	-	1.5			-	3.9			-	~5.4			-	7.0			-	~8.6		
Alkalinity (as $CaCO_3$)	mg/L	64.4 -	51.1 -	51.1 -	48.9 -	54.0 -	51.6 -	51.6 -	51.6 -	52.9 -	50.6 -	52.9 -	50.6 -	51.3 46.8	46.8 49.0	49.0 51.3	51.3 55.7	52.3 -	59.1 -	56.8 -	54.5 -
Fluoride	mg/L	0.7	0.3	0.7	0.4	-	-	-	-	0.2	0.3	0.2	0.3	-	-	-	-	0.5	0.3	0.3	0.2
Sulfate	mg/L	25.5	21.3	27.2	25.3	-	-	-	-	21.3	20.4	22.5	20.2	-	-	-	-	19.5	21.7	20.1	20.6
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	<0.05
Total P (as P)	µg/L	163 -	158 -	<10 -	60.7 -	149 -	<10 -	224 -	<10 -	167 -	<10 -	<10 -	23.0 -	219 298	96.5 96.5	<10 <10	<10 <10	154 -	139 -	<10 -	<10 -
Silica (as SiO_2)	mg/L	15.4 -	13.7 -	11.6 -	9.9 -	15.6 -	15.8 -	15.5 -	15.2 -	15.9 -	16.6 -	16.1 -	15.8 -	15.4 14.6	15.4 14.9	15.1 15.0	15.1 14.8	15.5 -	15.6 -	15.9 -	15.9 -
Turbidity	NTU	2.1 -	0.5 -	0.9 -	0.3 -	5.4 -	1.7 -	3.5 -	1.1 -	1.9 -	1.0 -	0.7 -	0.3 -	3.2 1.4	0.4 0.9	1.5 1.2	0.5 0.7	2.7 -	0.8 -	0.5 -	0.5 -
pH	S.U.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Temperature	°C	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DO	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ORP	mV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Hardness (as $CaCO_3$)	mg/L	49.8	52.2	49.8	51.9	-	-	-	-	55.0	54.6	54.7	53.4	-	-	-	-	57.1	56.0	69.7	62.9
Ca Hardness (as $CaCO_3$)	mg/L	42.2	44.4	42.5	44.2	-	-	-	-	46.7	46.2	46.6	45.3	-	-	-	-	48.5	47.6	61.5	54.7
Mg Hardness (as $CaCO_3$)	mg/L	7.6	7.7	7.3	7.7	-	-	-	-	8.3	8.4	8.1	8.1	-	-	-	-	8.6	8.4	8.3	8.2
As (total)	µg/L	24.2 -	24.4 -	<0.1 -	3.9 -	24.2 -	0.3 -	<0.1 -	0.8 -	25.6 -	1.3 -	0.7 -	1.3 -	29.7 34.4	0.8 0.8	0.1 <0.1	0.6 0.5	17.2 -	1.9 -	<0.1 -	0.4 -
As (soluble)	µg/L	0.1	1.2	<0.1	1.3	-	-	-	-	25.6	1.3	0.6	3.2	-	-	-	-	17.3	1.9	<0.1	0.7
As (particulate)	µg/L	24.1	23.2	<0.1	2.6	-	-	-	-	<0.1	<0.1	<0.1	<0.1	-	-	-	-	<0.1	<0.1	<0.1	<0.1
As (III)	µg/L	0.1	<0.1	<0.1	0.1	-	-	-	-	2.2	1.0	0.7	0.6	-	-	-	-	1.8	0.5	0.2	0.1
As (V)	µg/L	<0.1	1.1	<0.1	1.2	-	-	-	-	23.4	0.2	<0.1	2.5	-	-	-	-	15.5	1.4	<0.1	0.6
Fe (total)	µg/L	31 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	392 1,054	<25 <25	<25 <25	<25 <25	30 -	<25 -	<25 -	<25 -
Fe (soluble)	µg/L	<25	<25	<25	<25	-	-	-	-	<25	<25	<25	<25	-	-	-	-	<25	<25	<25	<25
Mn (total)	µg/L	25.0 -	7.0 -	0.2 -	1.0 -	20.9 -	1.2 -	0.1 -	0.3 -	19.6 -	0.8 -	0.5 -	0.7 -	339 709	0.6 0.8	0.4 0.3	0.1 <0.1	42.8 -	1.5 -	0.4 -	0.2 -
Mn (soluble)	µg/L	0.3	6.9	<0.1	0.2	-	-	-	-	7.4	0.2	<0.1	0.6	-	-	-	-	10.6	0.1	0.2	0.4
Ti (total)	µg/L	2.6	1.8	1.0	1.3	-	-	-	-	-	-	-	-	-	-	-	-	1.8	1.4	1.2	1.0

Table B-1. Analytical Results from Treatment Plant Sampling at Pomfret, CT (Continued)

Sampling Date		03/03/10				03/18/10				04/01/10				04/15/10			
Sampling Location Parameter	Unit	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS
Bed Volume	10^3	-	10.3			-	12.0			-	~13.5			-	15.1		
Alkalinity (as $CaCO_3$)	mg/L	61.2 -	51.8 -	61.9 -	54.1 -	51.2 -	48.8 -	51.2 -	53.5 -	53.2 -	51.0 -	46.5 -	51.0 -	54.7 -	52.4 -	52.4 -	52.4 -
Fluoride	mg/L	-	-	-	-	0.2	0.2	0.2	0.2	-	-	-	-	0.2	0.3	0.2	0.3
Sulfate	mg/L	-	-	-	-	21.7	21.4	21.1	44.6	-	-	-	-	21.1	20.4	19.7	20.5
Nitrate (as N)	mg/L	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	<0.05
Total P (as P)	µg/L	153 -	147 -	<10 -	22.3 -	175 -	171 -	<10 -	<10 -	193 -	164 -	79.5 -	43.8 -	156 -	159 -	112 -	99.6 -
Silica (as SiO_2)	mg/L	14.2 -	14.1 -	14.2 -	14.1 -	15.8 -	15.6 -	16.5 -	16.1 -	15.1 -	15.5 -	15.8 -	15.6 -	14.5 -	14.7 -	14.8 -	14.7 -
Turbidity	NTU	1.9 -	0.3 -	0.3 -	0.4 -	2.8 -	0.5 -	0.6 -	0.2 -	0.7 -	1.0 -	1.2 -	0.5 -	1.1 -	0.7 -	0.7 -	0.5 -
pH	S.U.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Temperature	°C	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DO	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ORP	mV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	59.9	61.7	60.1	59.2	-	-	-	-	54.8	55.1	55.1	53.7
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	50.5	52.8	51.4	50.2	-	-	-	-	45.6	46.0	46.1	44.7
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	9.5	8.9	8.7	9.0	-	-	-	-	9.2	9.1	9.0	9.0
As (total)	µg/L	21.4 -	3.3 -	0.1 -	2.3 -	24.9 -	6.1 -	0.2 -	0.6 -	27.9 -	7.4 -	0.3 -	0.9 -	25.1 -	10.2 -	0.3 -	0.8 -
As (soluble)	µg/L	-	-	-	-	24.9	6.3	0.2	1.3	-	-	-	-	24.7	10.8	0.3	0.9
As (particulate)	µg/L	-	-	-	-	<0.1	<0.1	<0.1	<0.1	-	-	-	-	0.3	<0.1	<0.1	<0.1
As (III)	µg/L	-	-	-	-	0.6	0.8	0.2	0.1	-	-	-	-	5.9	0.4	0.2	<0.1
As (V)	µg/L	-	-	-	-	24.3	5.5	<0.1	1.1	-	-	-	-	18.8	10.4	<0.1	0.8
Fe (total)	µg/L	37 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	349 -	<25 -	<25 -	<25 -	46 -	<25 -	<25 -	<25 -
Fe (soluble)	µg/L	-	-	-	-	<25	<25	<25	<25	-	-	-	-	<25	<25	<25	<25
Mn (total)	µg/L	49.8 -	0.2 -	<0.1 -	0.4 -	19.9 -	2.7 -	0.1 -	0.4 -	196 -	0.9 -	0.4 -	0.2 -	37.2 -	0.7 -	0.1 -	0.2 -
Mn (soluble)	µg/L	-	-	-	-	7.5	0.1	<0.1	0.2	-	-	-	-	10.2	0.1	<0.1	<0.1
Ti (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table B-1. Analytical Results from Treatment Plant Sampling at Pomfret, CT (Continued)

Sampling Date		04/29/10				05/18/10				05/27/10				06/10/10			
Sampling Location Parameter	Unit	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS
Bed Volume	10^3	-	16.6			-	19.0			-	20.0			-	21.6		
Alkalinity (as $CaCO_3$)	mg/L	51.4 51.4	51.4 62.6	51.4 51.4	53.6 -	53.2 -	50.9 -	50.9 -	53.2 -	48.6 -	48.6 -	48.6 -	50.9 -	52.3 -	47.7 -	50.0 -	50.0 -
Fluoride	mg/L	-	-	-	-	0.2	0.2	0.2	0.2	-	-	-	-	0.3	0.3	0.2	0.3
Sulfate	mg/L	-	-	-	-	20.2	18.7	19.8	18.8	-	-	-	-	21.3	20.5	21.3	19.3
Nitrate (as N)	mg/L	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	<0.05
Total P (as P)	µg/L	179 172	186 177	154 147	139 136	137 -	151 -	147 -	139 -	160 -	170 -	152 -	155 -	57.2 -	177 -	161 -	161 -
Silica (as SiO_2)	mg/L	14 14.1	13.8 14.1	14.0 14.0	14.1 -	15.6 -	15.8 -	15.0 -	15.0 -	14.7 -	14.8 -	15.0 -	14.9 -	14.4 -	14.5 -	14.9 -	15.2 -
Turbidity	NTU	1.3 1.0	1.5 1.4	0.7 0.7	0.2 -	0.9 -	1.7 -	0.4 -	0.2 -	1.7 -	3.4 -	2.1 -	0.2 -	1.0 -	0.5 -	0.6 -	0.3 -
pH	S.U.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Temperature	°C	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DO	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ORP	mV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	57.2	66.0	68.1	58.6	-	-	-	-	59.5	58.8	59.3	60.1
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	48.4	56.1	58.0	49.3	-	-	-	-	52.4	49.9	50.6	51.2
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	8.9	9.9	10.1	9.3	-	-	-	-	7.1	8.9	8.7	8.9
As (total)	µg/L	26.5 26.0	12.8 12.3	0.2 0.2	0.7 0.7	23.2 -	13.3 -	0.4 -	0.9 -	25.1 -	13.9 -	0.6 -	0.9 -	22.7 -	15.5 -	1.0 -	1.4 -
As (soluble)	µg/L	-	-	-	-	23.1	13.2	0.4	2.3	-	-	-	-	22.8	16.0	1.0	1.3
As (particulate)	µg/L	-	-	-	-	<0.1	<0.1	<0.1	<0.1	-	-	-	-	<0.1	<0.1	<0.1	<0.1
As (III)	µg/L	-	-	-	-	0.9	0.2	0.1	0.1	-	-	-	-	2.0	0.2	0.2	0.2
As (V)	µg/L	-	-	-	-	22.2	13.1	0.3	2.2	-	-	-	-	20.7	15.8	0.8	1.2
Fe (total)	µg/L	<25 <25	<25 <25	<25 <25	<25 <25	<25 -	<25 -	<25 -	49.2 -	<25 -	<25 -	<25 -	<25 -	170 -	<25 -	<25 -	<25 -
Fe (soluble)	µg/L	-	-	-	-	<25	<25	<25	<25	-	-	-	-	<25	<25	<25	<25
Mn (total)	µg/L	18.0 18.2	0.1 0.2	0.2 <0.1	<0.1 0.1	14.8 -	0.4 -	0.1 -	0.4 -	25.2 -	0.2 -	<0.1 -	0.2 -	162 -	1.7 -	0.4 -	0.2 -
Mn (soluble)	µg/L	-	-	-	-	5.9	<0.1	<0.1	0.2	-	-	-	-	12.1	<0.1	<0.1	0.4
Ti (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	2.2	1.8	1.7	1.8

Table B-1. Analytical Results from Treatment Plant Sampling at Pomfret, CT (Continued)

Sampling Date		08/10/10				09/07/10				10/07/10			
Sampling Location Parameter	Unit	IN	TA	TB	DS	IN	TA	TB	DS	IN	TA	TB	DS
Bed Volume	10^3	-	29.1			-	32.3			-	~35.8		
Alkalinity (as $CaCO_3$)	mg/L	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	130 -	145 -	143 -	138 -	164 -	167 -	161 -	157 -	131 -	130 -	124 -	123 -
Silica (as SiO_2)	mg/L	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Turbidity	NTU	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
pH	S.U.	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	°C	-	-	-	-	-	-	-	-	-	-	-	-
DO	mg/L	-	-	-	-	-	-	-	-	-	-	-	-
ORP	mV	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	23.6 -	16.8 -	4.2 -	4.1 -	25.9 -	19.1 -	6.2 -	5.7 -	24.9 -	19.3 -	8.5 -	27.2 -
As (soluble)	µg/L	24.7	16.5	4.1	5.0	25.4	19.5	6.1	6.5	24.4	19.2	8.2	21.8
As (particulate)	µg/L	<0.1	0.3	0.1	<0.1	0.5	<0.1	<0.1	<0.1	0.5	<0.1	0.3	5.4
As (III)	µg/L	1.1	0.2	0.1	0.1	0.7	<0.1	<0.1	<0.1	1.0	0.3	0.2	0.7
As (V)	µg/L	23.6	16.4	3.9	4.9	24.7	19.4	6.0	6.4	23.4	18.9	8.0	21.1
Fe (total)	µg/L	52 -	<25 -	<25 -	<25 -	63 -	<25 -	<25 -	<25 -	317 -	<25 -	<25 -	<25 -
Fe (soluble)	µg/L	< 25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Mn (total)	µg/L	29.4 -	0.8 -	0.3 -	1.6 -	47.9 -	0.4 -	<0.1 -	<0.1 -	91.7 -	3.6 -	0.5 -	0.3 -
Mn (soluble)	µg/L	6.2	< 0.1	< 0.1	0.4	5.8	<0.1	<0.1	<0.1	6.2	<0.1	<0.1	3.8
Ti (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-